THE MEASUREMENT OF CRANIOFACIAL MORPHOLOGY HEAD POSTURE AND NASAL AIRFLOW IN PATIENTS WITH CONGENITAL CLEFTS OF THE LIP AND PALATE

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Thesis presented for the degree of
Doctor of Philosophy
of the University of Edinburgh

1987

ABSTRACT

The present study was both methodological and investigative in nature. This included the development of computerised rhinomanometry and establishment of cephalometric measurement apparatus together with a standardised lateral cephalometric radiography technique to record natural head posture.

The method errors of both the measurement systems and the operator were tested by duplicate determinations and subsequent statistical analysis. Recordings for all the variables in the study were reproducible without systematic error and with a very small method error.

Apparatus was used to record nasal respiratory resistance (NRR), craniofacial form and head posture in a control group for comparison with subjects with cleft lip (CL), cleft palate (CP), and unilateral cleft lip and palate (UCLP).

The results of the rhinomanometric recording indicated that the bilateral nasal resistance did not differ significantly between the cleft samples and the controls. Unilateral measurements of nasal resistance showed higher values for the cleft side than for the non-cleft side, both in cleft lip (CL) and the unilateral cleft lip and palate (UCLP) samples. In the cleft palate (CP) sample as well

as in the controls, unilateral nasal resistance did not differ between the two sides.

Comparisons were made between cephalometric measurements for craniofacial form and head posture for each category of the clefting deformity and the controls and the statistically significant differences tabulated.

Previous studies have demonstrated associations between cranio-cervical angulation and craniofacial morphology, and between airway adequacy and cranio-cervical angulation.

In the present study, differences and correlations were calculated between face height, head posture and airway resistance which were in agreement with the predicted pattern of associations between cranio-cervical angulation and craniofacial morphology (face height) and between airway adequacy and cranio-cervical angulation.

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ACKNOWLEDGEMENTS

The investigation was carried out in the Department of Preventive Dentistry of the University of Edinburgh, Scotland. The clinical measurements were made in the Edinburgh Dental Hospital and assembled over the period 1982 to 1985.

I am deeply indebted to Professor dr. odont Beni Solow of the Institute of Orthodontics, Royal Dental College, Copenhagen, and to Professor Philip Sutcliffe of the Department of Preventive Dentistry, University of Edinburgh for guidance and constructive criticism during the study.

I appreciate the co-operation of the Combined Cleft Lip and Palate team based at the Royal Hospital for Sick Children Edinburgh, who allowed me ready access to patients with cleft lip and palate deformity.

My thanks are due to the staff of the Department of Dental Radiology of Edinburgh Dental Hospital for use of facilities, and to Miss Ruth Duvall, superintendent radiographer, who carried out the radiography for the study.

The statistical calculations were carried out at the Northern European Computing Centre (NEUCC), Lyngby, Copenhagen, and the Department of Preventive Dentistry, University of Edinburgh. I acknowledge the help given at both of these centres but especially to Professor B. Solow in Copenhagen and to Miss B. Wohlgemuth in Edinburgh.

The computer programmes for cephalometric analysis were written by Mrs. Jean Taylor of Edinburgh Regional Computing Centre (ERCC) and I am indebted to her for all the help.

The illustrative work was carried out by Mr. D. Hunter, technical officer, Department of Preventive Dentistry and Mr. Ian Goddard, photographic technician, Department of Oral Medicine and Oral Pathology, University of Edinburgh.

Finally I wish to thank the patients who agreed to take part in the study, and to Miss Y. Stables who carried out the typing.

The financial support from the following funds is acknowledged: University of Edinburgh for facilities and equipment; Ethicon Ltd., Edinburgh; Mercury Electronics, Glasgow; and Orthomax Dental, Bradford for financial assistance towards travel expenses.

DECLARATION

This thesis is the original work of the author with the exception of the help and guidance acknowledged in the text.

GLOSSARY OF EQUIPMENT USED

a) Radiography

Cephalometric Radiography Machine

J. Morita Corporation,
11-13 2-Chome Ueno,
Taito-ku,
Tokyo 110,
Japan.

Panelipse with cephalometric attachment

Head Type 100 EC

Anode 3703

Tube E 75 21 N

Date of manufacture 1979

Serial Number 1465.

Parallel Grid

No. 68 02 830 G100E

Serial Number N70 136

Ratio 6:1

Size 24cm x 30cm

70 absorbing strips per centimetre.

Elema-Schönander,
Solna,
Sweden.

Cassette

Trimax T16 cassette

24cm x 30cm

Rare earth screens.

3M Company plc,
Scotland.

Radiographic Film

Trimax XD

24cm x 30cm.

3M Company plc,
Scotland.

b) **Rhinomanometry**

Rhinomanometric Machine

NR3 configuration - nasal resistance meter.

Based on two membrane type differential pressure transducers with threshold feature and preset pressure or flow channels.

Zero stability $\pm$2% at constant temperature.

Pneumotachograph resistance to Air-Flow-

Approximately 5mm H_2O at 500 cm^3/sec

Power supply	110/220/21/40 50Hz
Pressure range	$\pm$ 1000Pascals
Flow range	$\pm$ 1000cm^3/sec
Output voltage	1 volt DC at 10KΩ
Accuracy	$\pm$ 2%
Weight	4Kg
Size	11cm x 47cm x 25cm

Mercury Electronics,
Pollock Castle Estate,
Glasgow.

Computer

British Broadcasting Corporation Microcomputer System
(BBC Model B)

Acorn Computers,
Cambridge.

Printer

Epson FX80.

Epson UK plc,
Dorland House,
388 High Road,
Wembley,
Middlesex.

Monitor

Apple Monitor Model AZMZ010P
Green Phosphor Screen Serial No. 9952645

Apple Computer,
20525 Mariani Avenue,
Cupertino,
California 95014,
U.S.A.

Calibration Unit

Dynamic calibration machine.

Producing pressure peak at 500 Pascals.

Flow peak at 150 Litres/sec^3.

Mercury Electronics,
Pollock Castle Estate,
Newton Mearns,
Glasgow.

Nasal Catheter Adhesive Tape

Leukoflex tape.

Beiersdorf AG,
Hamburgh,
West Germany.

Oral Catheter Tips

4mm Otoscope disposable tips.

Keeler Medical Manufacturing,
London.

Nasal Spray

Otrivine Decongestant

Xylometazoline hydrochloride B.P.

0.1%

Ciba Laboratories,
Horsham,
West Sussex.

c) **Digitiser**

SAC GP-7.

Science Accessories Corporation,
Southport,
Connecticut,
U.S.A.

CHAPTER 1

INTRODUCTION

The mechanisms that control facial growth and development are still not known. One method of studying these mechanisms is the careful analysis of subjects with aberrant growth due to developmental anomalies and the comparison of this data with similar measurements obtained from a control group.

Previous studies using cephalometric radiographs have shown that the average form of the cranial base and the mandible in subjects with clefting deformity of the face differs from that of normal subjects (Dahl 1970). In addition rhinomanometric studies have shown that nasal airflow in such subjects is reduced (Warren *et al* 1969).

It has been shown in normal subjects that head posture is related to facial development (Solow *et al* 1976) and also to nasal resistance (Solow *et al* 1979).

Increase in nasal resistance has an influence on the development of the dentition and the craniofacial morphology (Linder-Aronson 1970), and different categories of clefting deformity also have different effects on the dentition and cranio-facial form (Dahl 1970).

The aim of the present investigation was to collect data for craniofacial morphology, head posture and nasal airway resistance in subjects with various categories of cleft lip and palate for comparison with a control group. The measurement error for equipment used in the study was tested to enable reproducible values to be recorded for each of the sets of measurements. Bilateral and unilateral recordings of nasal respiratory resistance were carried out to detect whether a differentiated pattern existed between the cleft groups which were associated with changes in cranio-cervical angulation and lower face height.

CHAPTER 2

LITERATURE

1. Rhinomanometry

Rhinomanometry is the term given to the measurement of nasal resistance to airflow. The regulating mechanisms that control this airflow are complex and the accurate recording of nasal respiratory resistance (NRR) is important if the diagnostic value of the technique is to become well established. Many methods have been published for recording and measurement (Aschan et al 1958; Rasmus & Jacobs 1969; Maran et al 1971; Kern 1973; Mackay 1979; Masing 1979; Broms et al 1979; Mygind 1980; Solow & Greve 1980; Gurley & Vig 1982), but until recently no standards have been set, although suggestions concerning standards had previously been made by Kern (1973, 1977, 1981) and Broms et al (1982b). In 1983 the first International Meeting on Standardisation of Rhinomanometry was held in Brussels, Belgium and recommendations were made concerning terminology, methods of measurement, calibration and expression of results (Clement 1984).

Stoksted (1951) one of the early workers in rhinomanometry used results derived from manometric measurements and studied school children with adenoid vegetations before and after surgical removal. He further developed the method and described its use as a diagnostic tool in other rhinology problems (Stoksted (1959). He showed that the nasal airway on each side undergoes cyclic changes: the mucosa on one side swelling whilst that on the other side shrinks. The total respiratory resistance remaining constant despite the change, provided external conditions did not alter.

Aschan et al (1958) used a small mask placed over the nose to measure total nasal resistance and used the pressure flow equation to calculate nasal respiratory resistance (NRR):

$$NRR = P/V$$

where P = pressure difference between the naso-pharynx and atmosphere and V = the flow recorded through the nose at this pressure. They suggested that nasal resistance could be measured in a single nostril by obliterating the other with a damp cotton wool roll. Failure to appreciate that the total nasal resistance measured, using both nostrils, is made up the resistance of both halves of the nasal compartments together with the resistance of the pharyngeal component of resistance lead to inaccuracies. The unilateral measurements therefore did not record nasal resistance of each half of the nose, but resistance of one half plus the naso-pharyngeal component. Their work was however important because the technique and method of calculation of nasal respiratory resistance (NRR) forms the basis of methodology in use at present.

Drettner (1960) used this technique in a series of 63 cases of patients with cleft palate and cleft lip and palate to investigate nasal airway and hearing. The incidence of both aural pathology and nasal obstruction was significantly greater in cases of cleft lip and palate when compared to cases with cleft palate only. He further observed that the nasal airway narrowing was caused by hyperplasia of the conchae, deviation of the septum and nasal aperture stenosis. In unilateral cleft of the lip and palate the deviation of the septum was almost always to the side of the cleft.

The technique proposed by Aschan (1958) was used by Linder-Aronson (1970) in a study to measure nasal airflow in subjects with enlarged adenoids. He demonstrated that nasal airflow was low in children with large adenoids and high in those with small adenoids and that airflow increased after adenoidectomy.

Further developments of the technique for measurement of nasal resistance were suggested by Inglestedt et al (1969) who used the measurement of a pressure drop at a fixed flow through a flow regulator to enable calculations of resistance to be made. They were aware that nasal resistance increases with flow rate and that the determinations should be made at a fixed flow rate to enable comparisons to be made. The study concentrated on total, or bilateral resistance measurements, but it was emphasised that the whole nose as well as each cavity should be tested, as compensation of erectile tissue in one nostril can mask a complete obstruction in the other.

In a study by Fischer (1970) a technique for nasal resistance measurement of the right and left nasal cavities was proposed. The measurement of pressure difference at the opposite nostril while measuring the flow in the other enabled more accurate calculations of resistance of right and left components to be made. This development improved the diagnostic value of the rhinomanometer and a modification of this technique for anterior measurements has been used in this study. Using this technique, Kortekangas (1972) compared the differences between values obtained by rhinomanometry for anterior (unilateral) and posterior (bilateral) measurements.

Bachman (1973,1976) proposed the delineation of a threshold value using a fixed pressure, with the calculation for nasal resistance being made from a reading of the flow at this pressure on the Y axis of an X/Y plot from the measurement apparatus (Bachman et al 1984)

The further development of rhinomanometric recording has used the advantages of recent computer technology developments of which the present study has contributed to the development of accurate measurement apparatus for routine clinical use with the advantage of rapid and easy calibration.

Few studies have investigated the nasal resistance of subjects with clefting deformity of the lip and palate. A study by Drettner (1960) was limited by the lack of clear definition of the categories of clefting and the size of the nasal airway was calculated rather than the values of nasal resistance. The failure rate of almost 20% of subjects who had difficulty in producing a satisfactory respiratory curve was high.

A second study was carried out by Warren et al (1969) who compared the nasal pathway resistance in normal and cleft lip and palate subjects. The study investigated 29 patients, with no clear definition of anomaly groups. Values for posterior nasal resistance were recorded and statistical comparisons made. Although the mean nasal pathway resistance was generally higher in the total cleft sample only borderline significance was detected in the 12-13 year old group.

Previous studies involving measurements of nasal resistance in normal children have, however, been carried out (Solow & Greve 1980; Saito & Nishihata 1981; Principato & Wolf 1985). The aim of the rhinomanometric component of the present investigation was to measure accurately the nasal resistance values for each category of cleft and each upper airway compartment to detect if a differentiated pattern of increased nasal resistance existed between the sub-groups and the different nasal compartments.

2. Craniofacial Morphology, Head Posture and Nasal Airflow

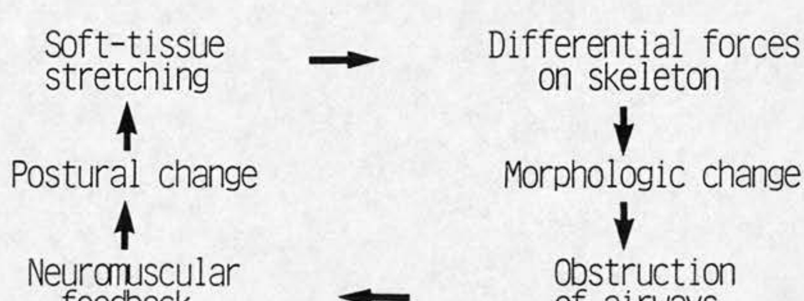
In a study of the effect of adenoids on the mode of breathing and the effect this had on the facial skeleton (Linder-Aronson & Backstrom 1960; Linder-Aronson 1970) it was demonstrated that patients with enlarged adenoid tissue are more likely than a control group to be mouthbreathers. The presence of this tissue in the naso-pharynx raises the overall nasal resistance to airflow and a point is reached where mouth breathing begins (Scweiger 1966). The effect of this in the growing child is for a longer lower face height, the so-called adenoid facies, to develop when comparisons are made to a control group. The effect on the dentition included retroclination of the lower incisors and reduction of the overjet, a narrow upper arch between first molars with crowding of the dentition and posterior crossbite.

In a follow-up study of the children who subsequently underwent adenoidectomy (Linder-Aronson 1974, 1975), it was found that the differences originally seen between the sample and the control group decreased significantly. This apparent change in growth direction implies some control mechanism at work. Linder-Aronson suggested that in mouthbreathing the tongue position is lowered. If the adenoids are then removed the resting tongue posture is raised resulting in reversal of the trend of changes which had taken place.

The changes associated with mouthbreathing are however very comprehensive and in recent studies (Solow & Tallgren 1976; Opedebeek et al 1978; Marcotte 1981; Sorensen et al 1980) it has been suggested that changed head posture might also be involved, although this was previously reported by Gresham & Smithells (1954).

Solow & Greve (1979) demonstrated the association between cranio-cervical angulation and respiratory resistance in a study of postural variables and nasopharyngeal dimensions in a group of children before and after adenoidectomy. The findings demonstrated that a large cranio-cervical angulation was seen in conjunction with a large nasal respiratory resistance (NRR) in a group of subjects before adenoidectomy. After the operative procedure nasal respiratory resistance and cranio-cervical angulation was reduced.

In order to explain the relationship between head posture, cranio-cervical angulation and craniofacial morphology, a hypothesis was suggested by Solow & Kreiborg (1977). Extension of the head may induce stretching of the facial soft tissues linking a chain of events to trigger a cycle:-



after Solow & Kreiborg (1977)

Since the vital function of head posture is to maintain airway it would not be surprising to find raised head posture in patients with difficulties in nasal respiration due to enlarged adenoids.

A detailed correlation study of head posture and craniofacial morphology by Solow & Tallgren (1976, 1977) highlighted a systematic set of associations between morphological and postural variables. Among the morphological characteristics of subjects with a large cranio-cervical angulation were a smaller facial prognathism, a larger mandibular plane inclination and a greater lower face height. These findings were similar to the findings on subjects with adenoidal obstruction of the airway and led to further investigations regarding the nature of the control mechanism involved in craniofacial growth.

Solow et al (1984) examined three sets of associations in a single non pathological group of subjects with no history of airway obstruction. Cephalometric radiographs taken in the normal postural position and rhinomanometric recordings were obtained and correlations were calculated between morphological, postural and airway variables. The observed correlations were in agreement with the predicted pattern of associations between craniofacial morphology, cranio-cervical angulation and airway resistance thus indicating the presence in a non pathological sample, of the same associations found in a sample with airway obstruction. The presence of a general control mechanism in craniofacial development was therefore proposed.

The accumulation of cephalometric radiographic data involves films being exposed with the patient in a natural head posture position (Moorrees & Keen 1958) This has been described by Solow & Tallgren (1971a, 1971b) and tested for reproducibility both as part of the present study and by Solow & Siersbaek-Nielsen (1982).

Studies in subjects with cleft lip and palate (Drettner 1960; Warren et al 1969; Warren et al 1974) indicate that respiratory obstruction occurs in these patients.

In summary, relationships have been found between head posture and morphology, airway adequacy and morphology and head posture and airway adequacy in a group of normal subjects. The aim of the cephalometric part of the present investigation was to tabulate variables for craniofacial form for each category of cleft and for the control group. Based upon the results of previous investigations, patients with clefting deformity may be expected to have a higher nasal resistance than normal subjects. Cleft palate subjects may also be expected to display changes in head posture and in craniofacial morphology associated with the expected increase in nasal resistance. The aim of this study is to determine the extent to which these expected changes could be demonstrated in a group of cleft palate patients when compared with normal subjects.

CHAPTER 3

SUBJECTS

The cleft sample consisted of 61 patients (35 males, 26 females) attending the Orthodontic Department of Edinburgh Dental Hospital. The sample comprised 15 patients with cleft lip (CL) (mean age 13.4, median age 14 years) 19 patients with cleft palate (mean age 12.7, median age 12 years) and 27 patients with unilateral cleft lip and palate (mean age 16.4, median age 16 years) (Tables 1, 2 & 3); (Figs. 1b, c & d).

All the cleft subjects were selected on the basis of the extent of the cleft (Table 4). In the cleft lip group only subjects with scar tissue involving the nasal aperture were included. In the cleft palate group, only patients with involvement of both hard and soft palate were included, and in the unilateral cleft lip and palate group only subjects with complete clefts of lip and palate were included. Patients with secondary surgical procedures such as adenoidectomy, tonsillectomy, pharyngeal flap or nasal septal surgery were excluded from the investigation, as were subjects with bilateral clefts involving lip and palate.

The control group consisted of 38 patients (19 male, 19 female) (mean age 14.4, median age 12 years) who were sequentially referred for orthodontic treatment. No patients had cross bites unilaterally

TABLE 1

Survey of the Sample

Diagnostic Group	Male N	Male %	Female N	Female %	Total N	Total %
Cleft Lip	7	20.0	8	30.8	15	24.6
Cleft Palate	10	28.6	9	34.6	19	31.1
Unilateral Cleft Lip and Palate	18	51.4	9	34.6	27	44.3
Total Cleft Sample	35		26		61	
Control	19		19		38	

TABLE 2

Ages of the Sample

Diagnostic Group	$\bar{x}$	Standard Deviation	Range
Cleft Lip	13.4	6.112	4.0 - 23.0
Cleft Palate	12.7	3.016	9.0 - 20.0
Unilateral Cleft Lip and Palate	16.4	4.498	8.0 - 23.0
Control	14.4	4.005	9.0 - 26.0

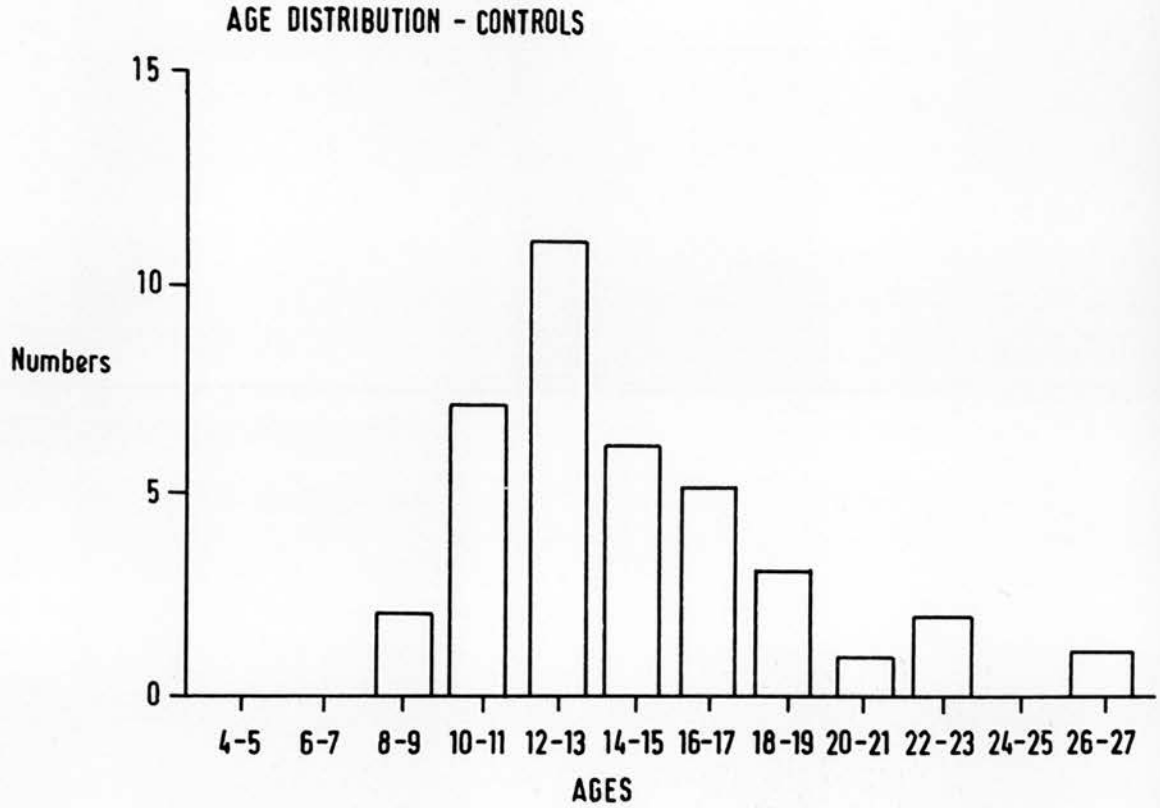
TABLE 3

Age Distribution of the Control Group and the Cleft Sample

Age in years N	Cleft lip N	Cleft palate N	Cleft lip and palate N	Control N
4 - 5	1	0	0	0
6 - 7	2	0	0	0
8 - 9	3	1	1	2
10 - 11	0	7	3	7
12 - 13	1	5	6	11
14 - 15	1	2	1	6
16 - 17	2	2	3	5
18 - 19	3	1	7	3
20 - 21	0	1	3	1
22 - 23	2	0	3	2
24 - 25	0	0	0	0
26 - 27	0	0	0	1
Total	15	19	27	38

Fig. 1a Age distribution of the control sample.

Fig. 1b Age distribution of the cleft lip (CL) sample.


AGE DISTRIBUTION - CONTROLS
Numbers
15
10
5
0
4-5 6-7 8-9 10-11 12-13 14-15 16-17 18-19 20-21 22-23 24-25 26-27
AGES

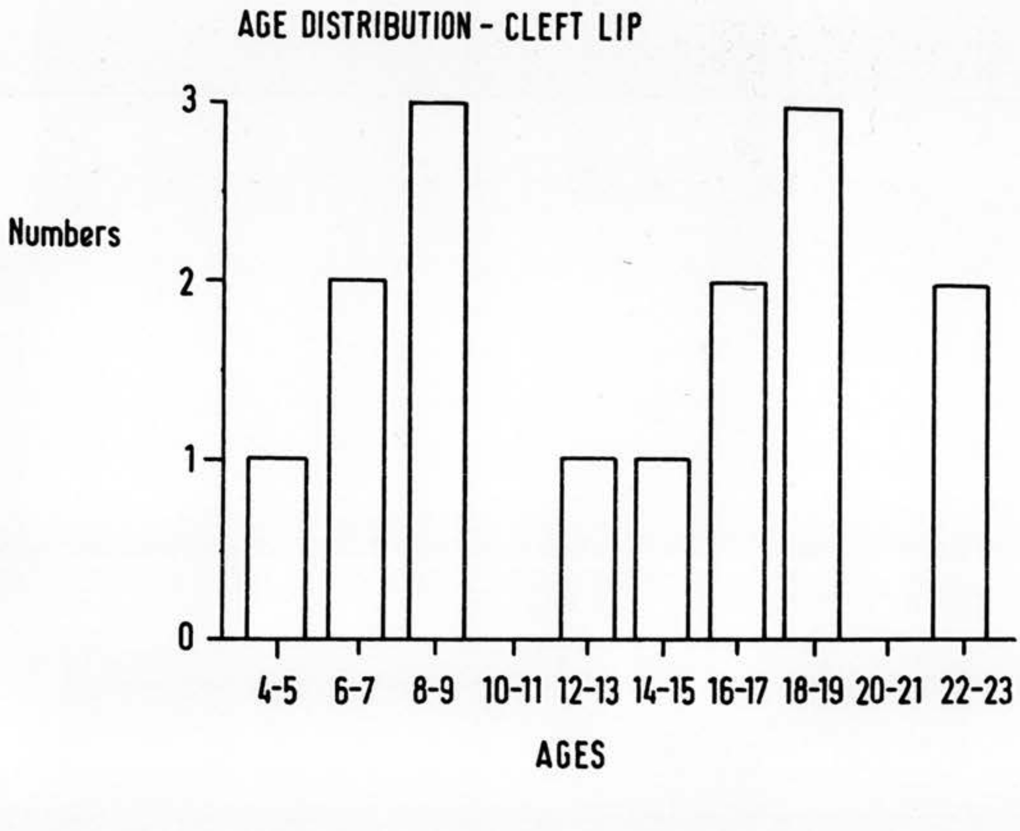
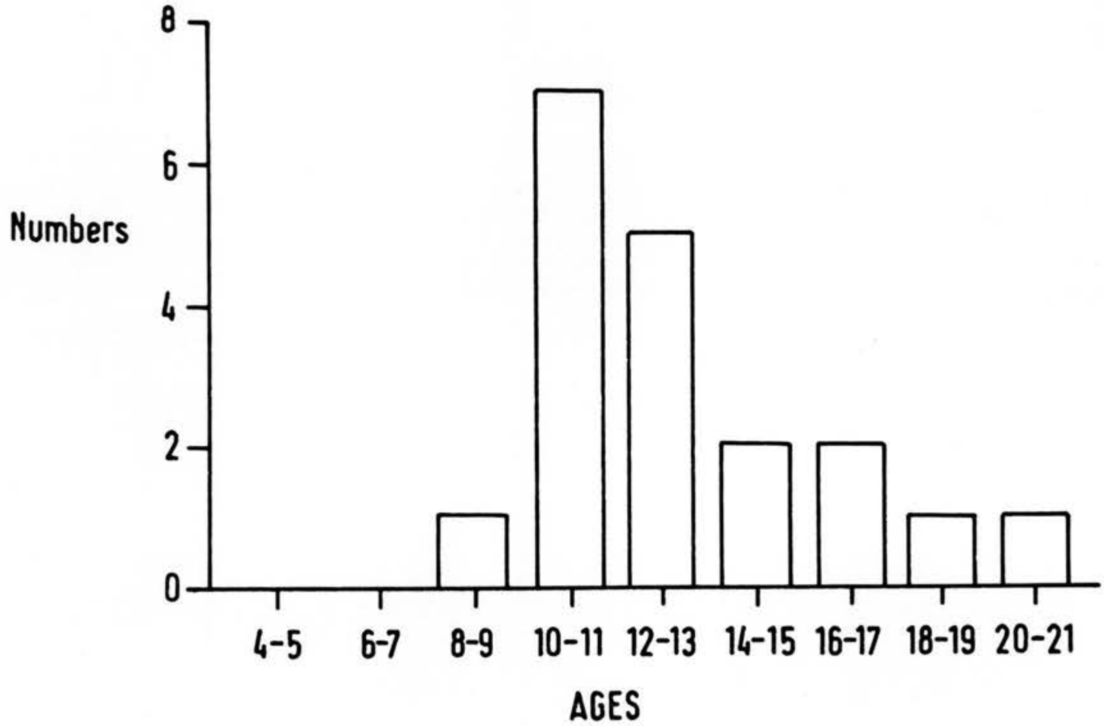

AGE DISTRIBUTION - CLEFT LIP
Numbers
3
2
1
0
4-5 6-7 8-9 10-11 12-13 14-15 16-17 18-19 20-21 22-23
AGES

Fig. 1c Age distribution of the cleft palate (CP) sample.

Fig. 1d Age distribution of the unilateral cleft lip and palate (UCLP) sample.

AGE DISTRIBUTION - CLEFT PALATE



AGE DISTRIBUTION - UNILATERAL CLEFT LIP & PALATE

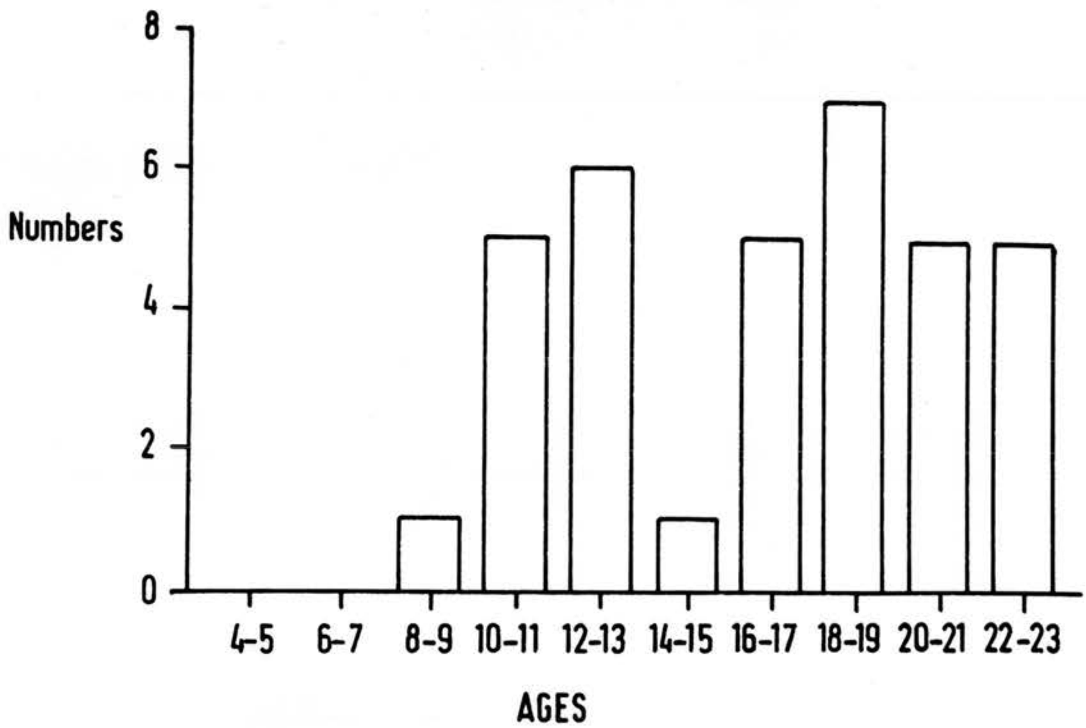


TABLE 4

Classification of Clefting Deformity

Type 1 Cleft Lip (CL)

Type 2 Cleft Palate (CP)

Type 3 Unilateral Cleft Lip and Palate (UCLP)

Type 4 Bilateral Cleft Lip and Palate (BCLP)*

* Type 4 (BCLP) not included in the study

or bilaterally and no patients were included who required a combination of orthodontics and oral surgery to deal with the malocclusion (Fig. 1a); (Tables 1, 2 & 3).

Clefts of the lip (CL) involve soft tissues and alveolar bone (Pruzansky 1953), the posterior limit of the defect being the incisive foramen. These structures are derived from the primary embryonic palate, and although a soft tissue defect only may be observed, radiographic examination reveals associated alveolar defects.

Clefts of the palate (CP) involve midline defects of the hard and soft palate with the anterior limit at the incisive foramen. Like the soft tissue deformity in cleft lip, clefts of the soft palate have a similar bony involvement. The soft palate clefts may have a sub-mucous extension that involves the hard palate.

Clefts of the lip and palate (UCLP, BCLP) involve a defect of fusion in both primary and secondary palate. The expression of the deformity may be unilateral (UCLP), or bilateral (BCLP), and may be only partially complete.

Only subjects with unilateral clefting deformity were included in the study because a detailed analysis of rhinomanometric values would have been difficult with a deformity involving both nasal apertures (Table 2).

The diagnosis of the cleft category was confirmed at the initial examination by the author.

1. **Cleft Lip and Palate Subjects**

The material was collected during the period of the study from 1982 to 1986. The Dental Hospital in Edinburgh is responsible for pre-surgical orthopaedic and post-surgical orthodontic treatment of patients with cleft lip and palate born in the Lothian Area of Scotland. Assessment and review of these patients takes place by the Combined Cleft Lip and Palate Team at the Royal Hospital for Sick Children in Edinburgh. This is a multidisciplinary team representing Plastic Surgery, Orthodontics, Otorhino-Laryngology and Speech Therapy.

Ethical approval for the research was obtained from the Lothian Area Dental Ethical Committee prior to the study, the clinicians from the combined cleft lip and palate clinic also gave their approval (Appendix 1).

Patients in the anomaly group, cleft lip (CL), cleft palate (CP) and unilateral cleft lip and palate (UCLP), were all subjects attending for clinical review. Children under the age of 4 years were excluded due to co-operation problems with rhinomanometric measurements. Both male and female patients were included in the study.

Radiographic assessments are made from time to time as the child grows and develops. It was therefore possible to obtain standardised cephalometric radiographic views at a routine review appointment at the Dental Hospital and then combine this with measurements of nasal resistance. All the radiographs were taken by the same radiographer and all the rhinomanometric assessments were carried out by the author.

2. **Control Group**

The control group consisted of 38 sequentially referred patients (19 male, 19 female) to the Orthodontic Department of the Edinburgh Dental Hospital. None of the patients in the control had received orthodontic treatment. The clinical, radiographic and rhinomanometric examination took place at the initial visit to the Orthodontic Department. The radiographic views were used for orthodontic diagnostic purposes as well as for the study. Both male and female subjects were included in the control sample.

CHAPTER 4

METHODS

1. Clinical Procedures used in the Study

Each patient from the control group and the anomaly sample was administered, on arrival, xylometazoline hydrochloride (Otrivine) as a nasal spray to each nostril. The subject was asked to sit quietly without blowing the nose for 5 minutes.

Radiographs were than taken with the subject standardised for natural head posture (Fig. 2).

Rhinomanometric recordings followed with the patient seated in front of the monitor of the rhinomanometer which displayed the sigmoid curve trace of the respiratory cycle (Fig. 3), providing visual feedback and enhanced accuracy. All recordings of nasal respiratory resistance (NRR) took place at least half an hour after the administration of the nasal spray. Unilateral (anterior) measurements of nasal respiratory resistance were carried out initially, followed by bilateral (posterior) measurements, mean values for 16 respiratory cycles being recorded.

Scrutiny of the standardised lateral cephalometric radiographs took place prior to departure of the patient and any repeat exposure that was required for poor image quality, incorrect occlusal registration or failure to include all head structures was carried out.

These repeat radiographs were used in order to assess method error for head posture variability in duplicate films for 12 subjects from the control group, when comparisons were made between cranio-cervical postural variables.

To assess the error of the method for rhinomanometric recordings, 12 subjects from the total sample had measurements of nasal respiratory resistance (NRR) made before and after radiographs were taken. An interval therefore occurred between the two sets of recordings. The comparison was made between the mean of the last four respiratory cycles for the first measurements with four respiratory cycles for the second measurement.

2. **Measurements Obtained for the Study**

For each subject, values for nasal resistance were obtained using a computerised rhinomanometer (Mercury NR3) (Fig. 3), and standardised lateral cephalometric skull radiographs were obtained (Fig.4). Prior to exposure of the film for the cephalometric lateral skull radiograph the patient was positioned in the natural head posture position (Solow & Tallgren 1971a, 1971b) (Fig.2). The reproducibility of natural head position was tested as part of this study. The results support previous findings by Siersbaek-Nielsen

Fig. 2 Subject in natural head posture prior to exposure of film.

Fig. 3 Mercury NR 3 computerised rhinomanometer, monitor and printer with calibration unit.


Media-Stor

Fig. 4 Standardized lateral cephalometric radiograph taken of a subject in the natural postural head position. Silver plumbline represents the true vertical.

& Solow (1982), that this head posture is reproducible without systematic error. Reference points on the lateral skull cephalometric films were obtained using a digitiser computerised system to record co-ordinates for each defined skull point. Angular and linear dimensions were then computed to enable statistical analysis of the data.

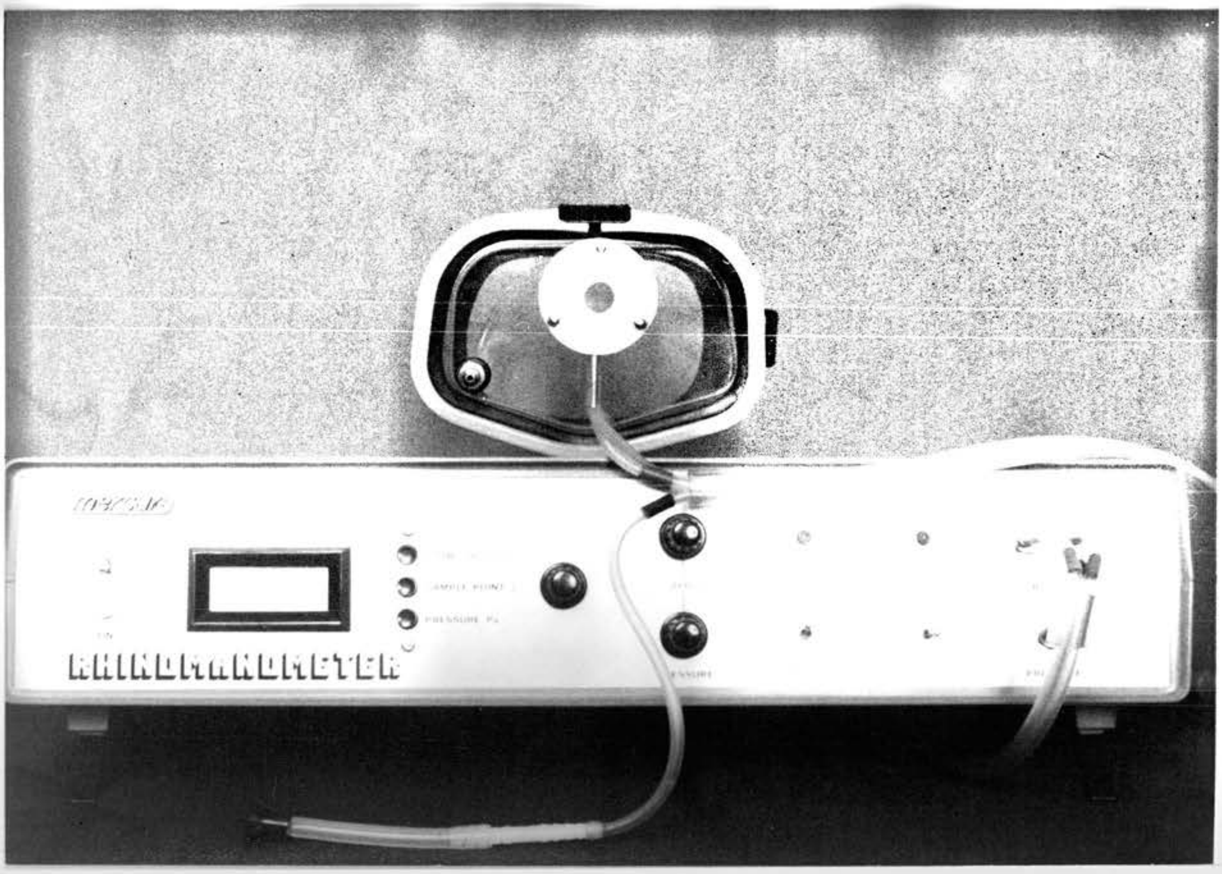
a **Equipment used in the investigation**

i) Rhinomanometric

A pilot study was carried out with a commercially available rhinomanometer NR1 (Mercury Electronics) (Fig. 5). This equipment had a liquid crystal display and measurements of airflow at a fixed pressure, or pressure at a fixed flow could be read from the meter. The liquid crystal display had a slow refresh rate and its response to the varying analogue input was inadequate. No visual feedback for the patient was available as suggested by Solow & Greve (1980) and the fit of the face mask provided was poor. No calibration device was available with the machine to test the accuracy of the measurement.

After initially proposing to increase the refresh rate of the liquid crystal display so a more rapid response occurred, it was decided to use the sigmoid curve produced on an X/Y plotter by the rhinomanometer (NR1) during a respiratory cycle. This could be

Fig. 5 Mercury NR1 Rhinomanometer.


RHINOMANOMETER

used for calculation of nasal respiratory resistance for one cycle of inspiration and expiration.

Recordings on a number of children were attempted but co-operation problems became apparent when numerous repeat measurements were required to obtain a mean value of nasal respiratory resistance for four respiratory cycles.

Further developments by Mercury Electronics led to the availability of a computerised rhinomanometer (NR3) using a BBC Model B computer and an Epson FX80 printer (Fig. 3). A prototype programme was available at that time which was modified for the requirements of the study by Professor B. Solow of the Royal Dental College, Copenhagen.

The programme was designed to calculate values for nasal respiratory resistance (NRR) at a preset pressure or preset flow threshold. The values for inspiration and expiration were displayed on a VDU monitor for each respiratory cycle and the mean values for four such measurements were calculated and shown on the screen. A visual feedback was provided for the patient on the VDU screen which displayed the pressure/flow curve from which the nasal respiratory resistance was calculated (Fig. 3).

This system of recording immediately overcame the difficulties experienced previously, but the problem of calibration of the recording device still remained to be solved. The initial calibration was carried out with a static pressure and flow signal to the pressure and flow channels of the rhinomanometer, the pressure being applied by the use of a calibrated water column manometer connected to a clinical syringe to apply a controlled pressure. The flow calibration was initially carried out by the Anaesthetic Department of the Edinburgh Royal Infirmary. These methods, although initially adequate, proved difficult for routine and frequent calibration of the equipment.

The need for a simple dynamic calibration device which could be installed adjacent to the rhinomanometer at the same room temperature was required.

Mercury Electronics constructed a dynamic pressure and flow calibration unit at the request of the author (Fig. 6) producing a flow that peaked at 150 cc/sec and a pressure that peaked at 500 Pascals. This dynamic signal resembled the normal respiratory cycle and this produced a sigmoid curve on the VDU (Fig. 6) which could be adjusted at calibration points on the rhinomanometer to peak to preset threshold values for flow and pressure. This provided the opportunity for easy and rapid calibration at the start of each recording session.

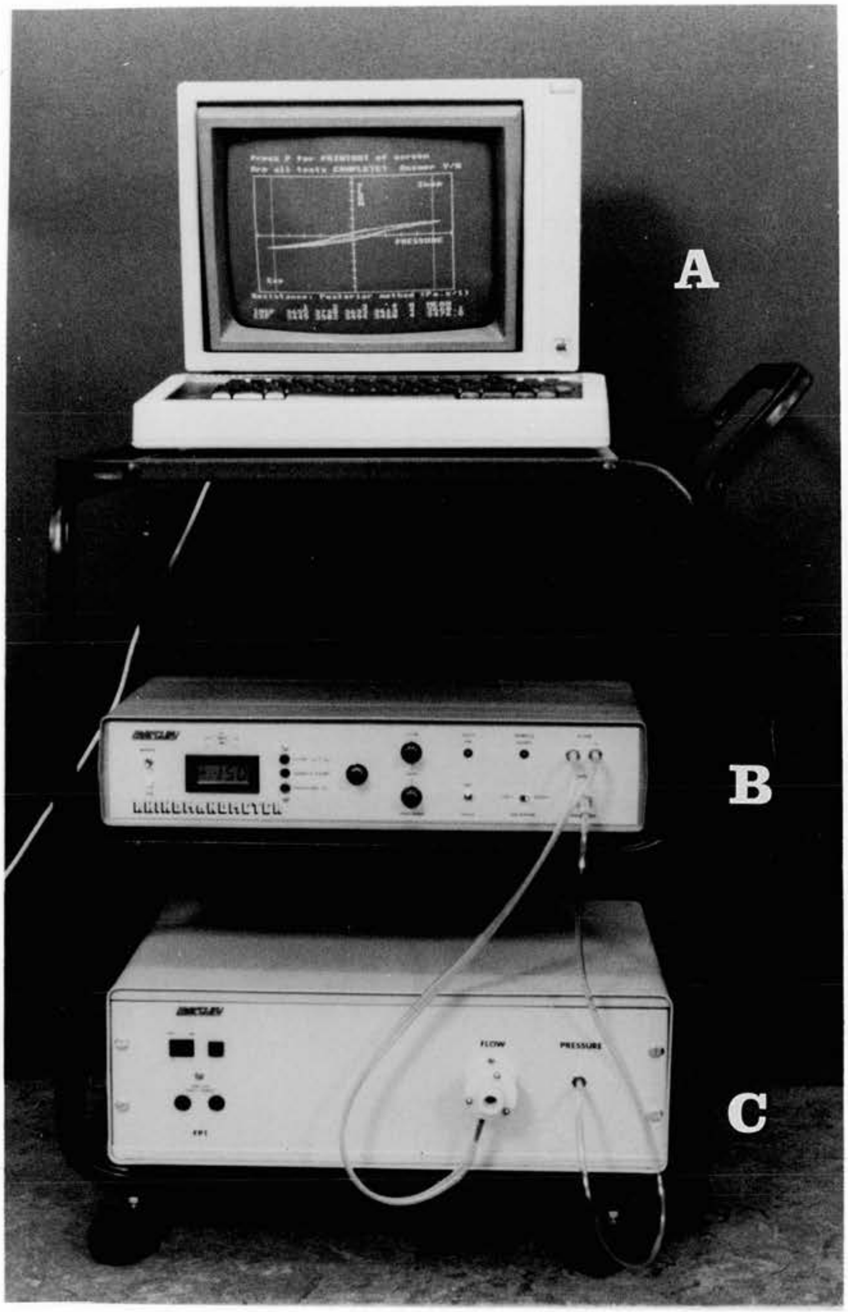
A schematic diagram (Fig. 7) shows the interelationships of the computerised rhinomanometry system set for calibration.

Fig. 6 Mercury NR3 rhinomanometer set for calibration.

A BBC microcomputer with monitor.

B Mercury NR3 rhinomanometer.

C Mercury FP1 calibration unit.


A
B
C
FLOW
PRESSURE

The rhinomanometer was kept switched on for the whole duration of the study as it was found to have a long warm-up time producing variation in measurements when the machine was switched on.

ii) Cephalometric

Standardised cephalometric radiographs were taken in a cephalostat incorporated into a Morita Panex EC orthopantomogram radiographic machine (Figs. 8 & 9). The machine was modified to produce lateral cephalometric skull radiographs with the long side of the film in true vertical and to include all the subject's head on the film. This involved alterations to the film holder (Fig. 10) and an adjustment to the primary filter arrangement at the exit point of the X-rays from the tube head (Fig. 11). The lead filter orifice was enlarged so as to expose the whole film in the vertical instead of horizontal position (Fig. 11).

For the lateral skull films, the subject was positioned in the natural head posture with the film placed on the right side of the face (Fig. 2). The positioning was carried out as described by Solow & Tallgren (1971a, 1971b).

The median plane was 15 cm from the film and the film focus distance was 150 cm (Fig. 8). The central ray passed through the ear rods and an aluminium wedge fixed at the primary filter (Fig. 11) reduced the exposure to the soft tissues, so enhancing the soft

Fig. 7 Schematic diagram to show the interelationships of the computerised rhinomanometry system set for calibration.

CALIBRATION
MODE

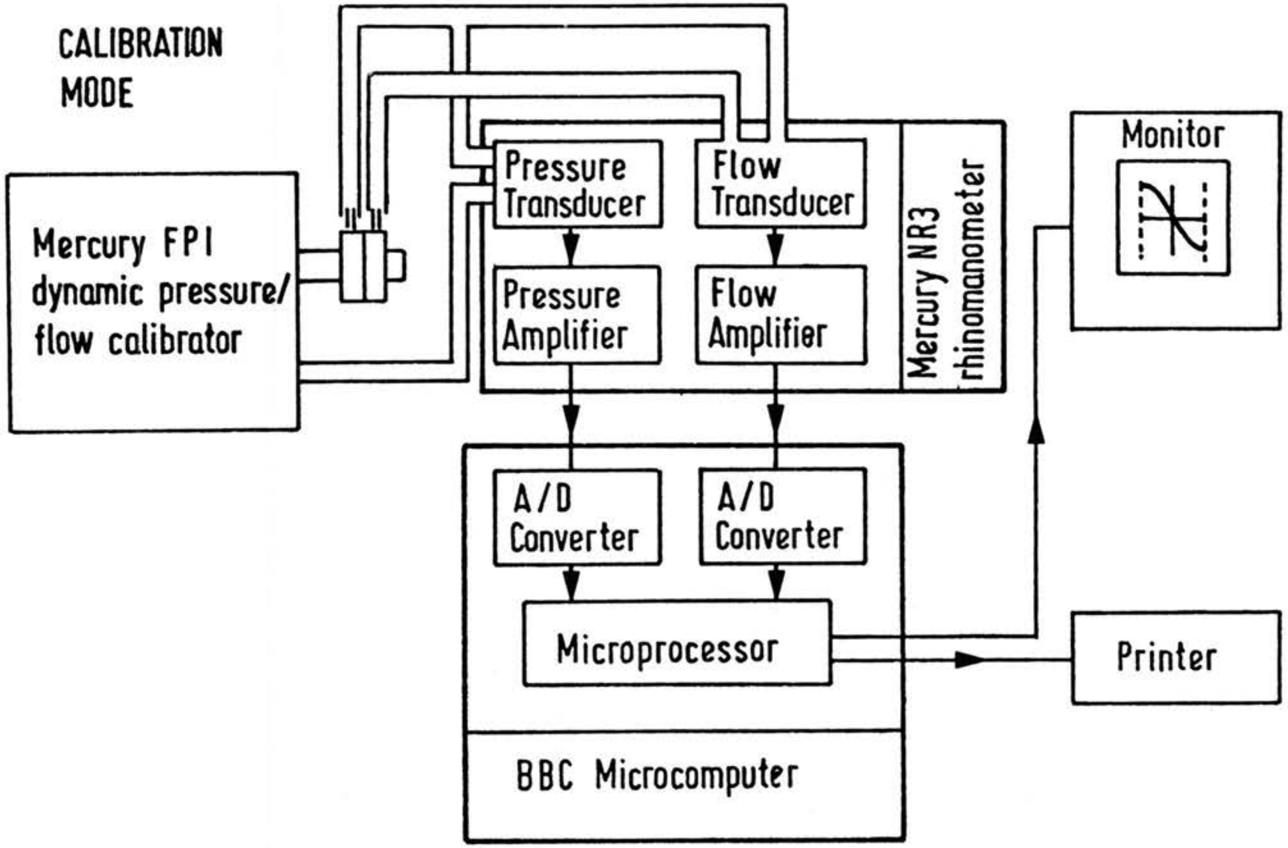
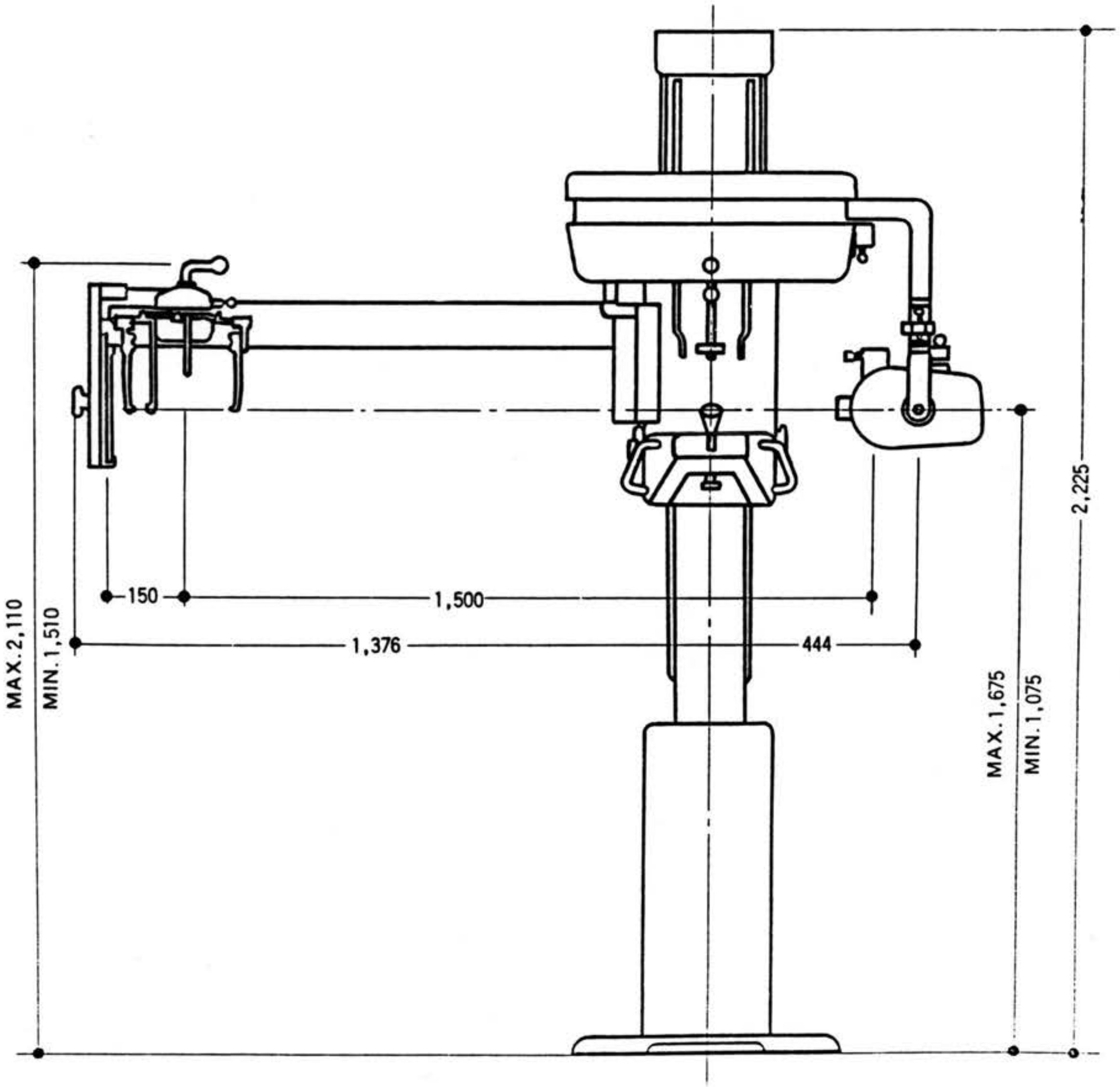


Fig. 8 Cephalometric radiography machine Morita Panex EC. Anode to midplane distance 150 cm. Midplane to film distance 15 cm.



2,225
MAX. 2,110
MIN. 1,510
150
1,500
1,376
444
MAX. 1,675
MIN. 1,075

Fig. 9 Cephalostat as used in the study for natural head posture recording.

A Film cassette with grid.

B Vertical plumbline.

C Mirror

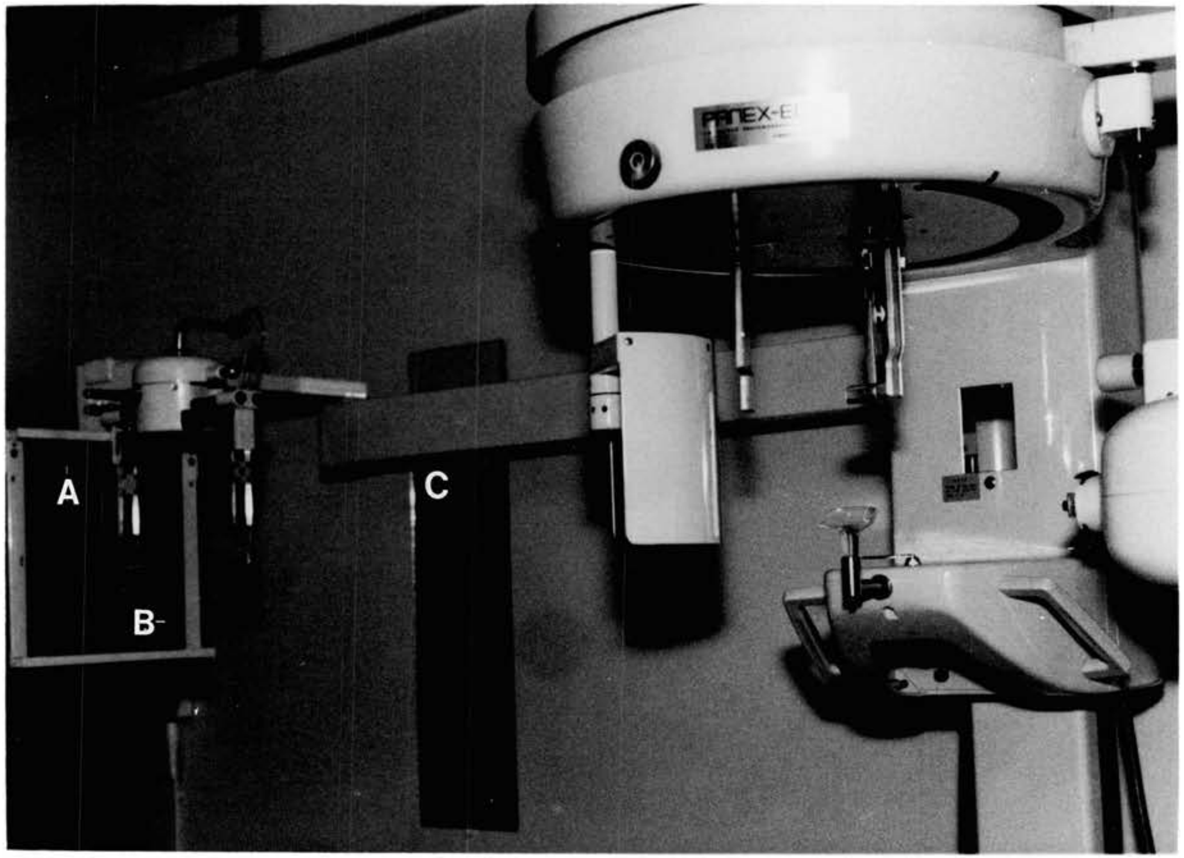

A
B
C

Fig. 10

A Film cassette.

B Grid.

C Vertical silver plumbline.

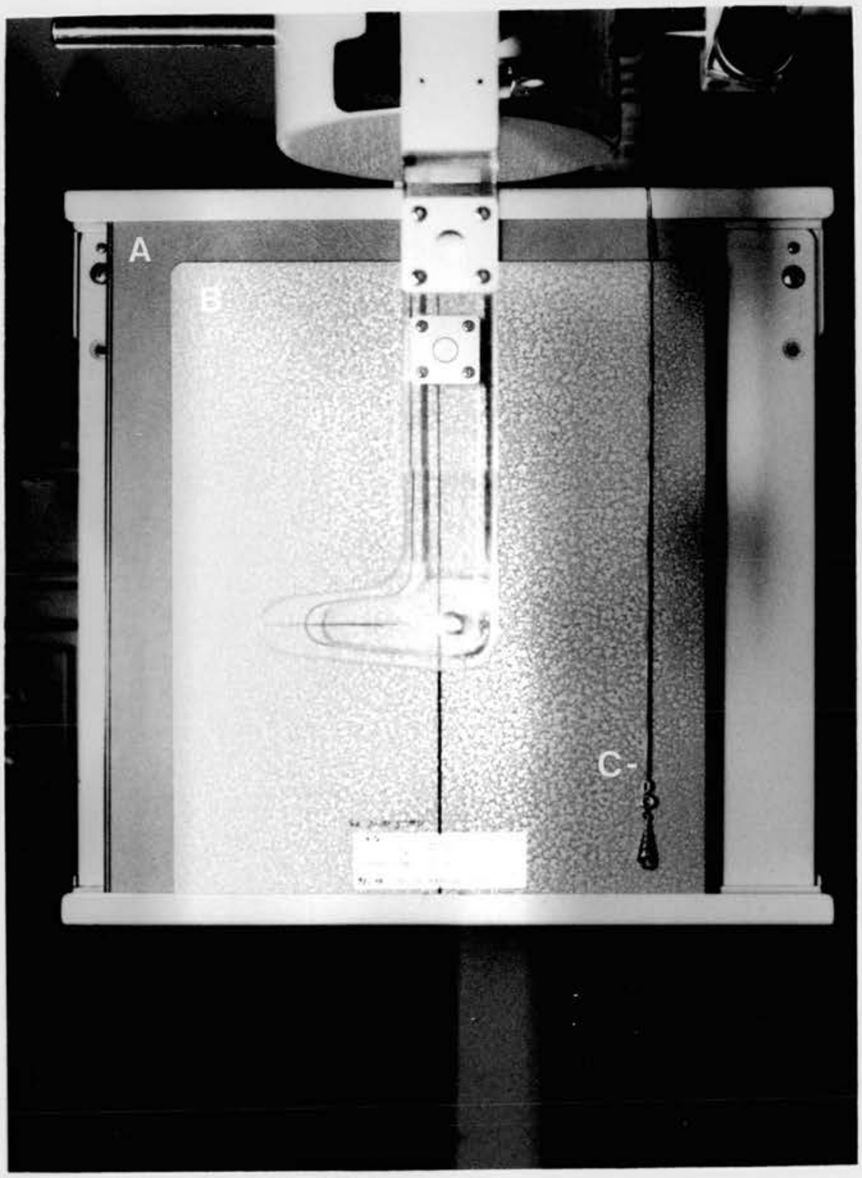
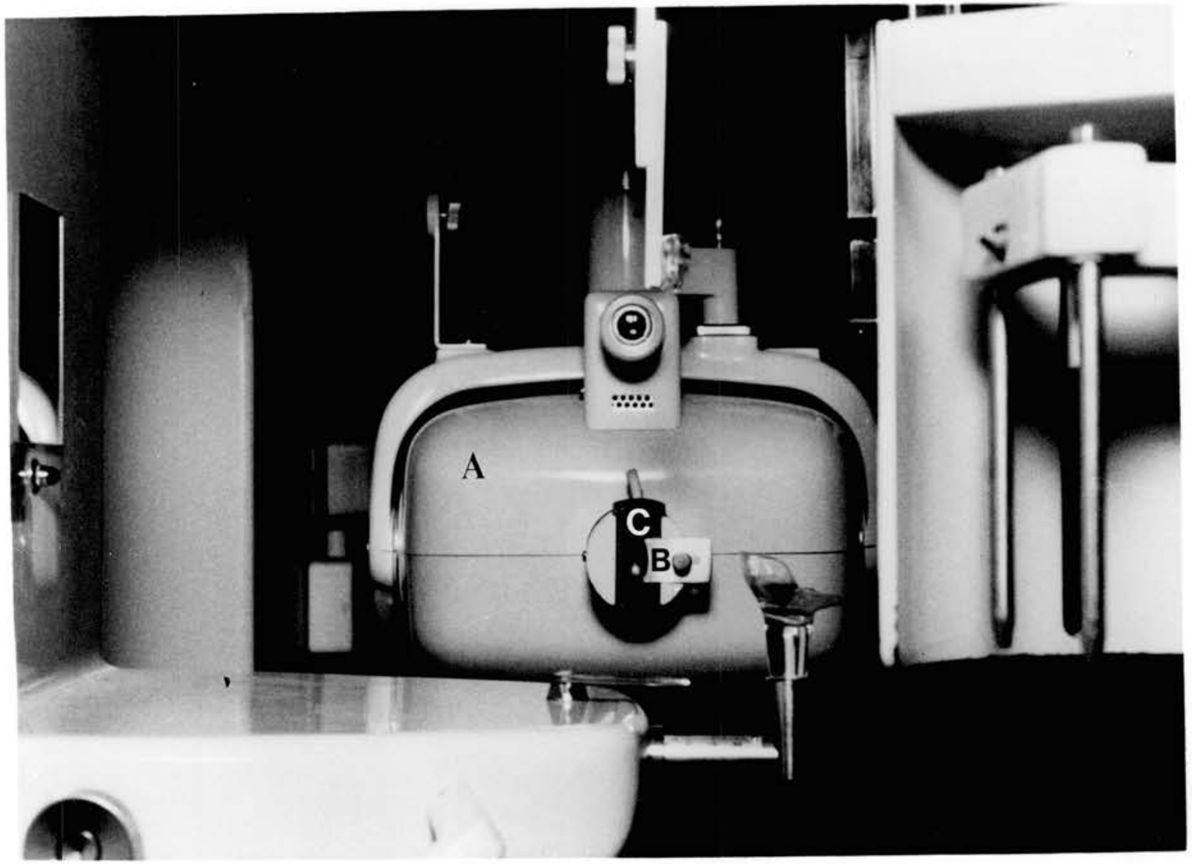

A
B
C-

Fig. 11 Modified primary filter in the head of the radiography machine.

A X-ray tube head.

B Aluminium filter.

C Primary lead filter with modified aperture.


A
C
B

tissue image quality. The exposures were made at 80 Kv and 90mA at 0.8 seconds using Trimax T16 cassettes with rare earth screens and Trimax XD fast radiographic film 24 cm x 30 cm, the exposure time being increased to 1.0 seconds for subjects aged 17 years and over.

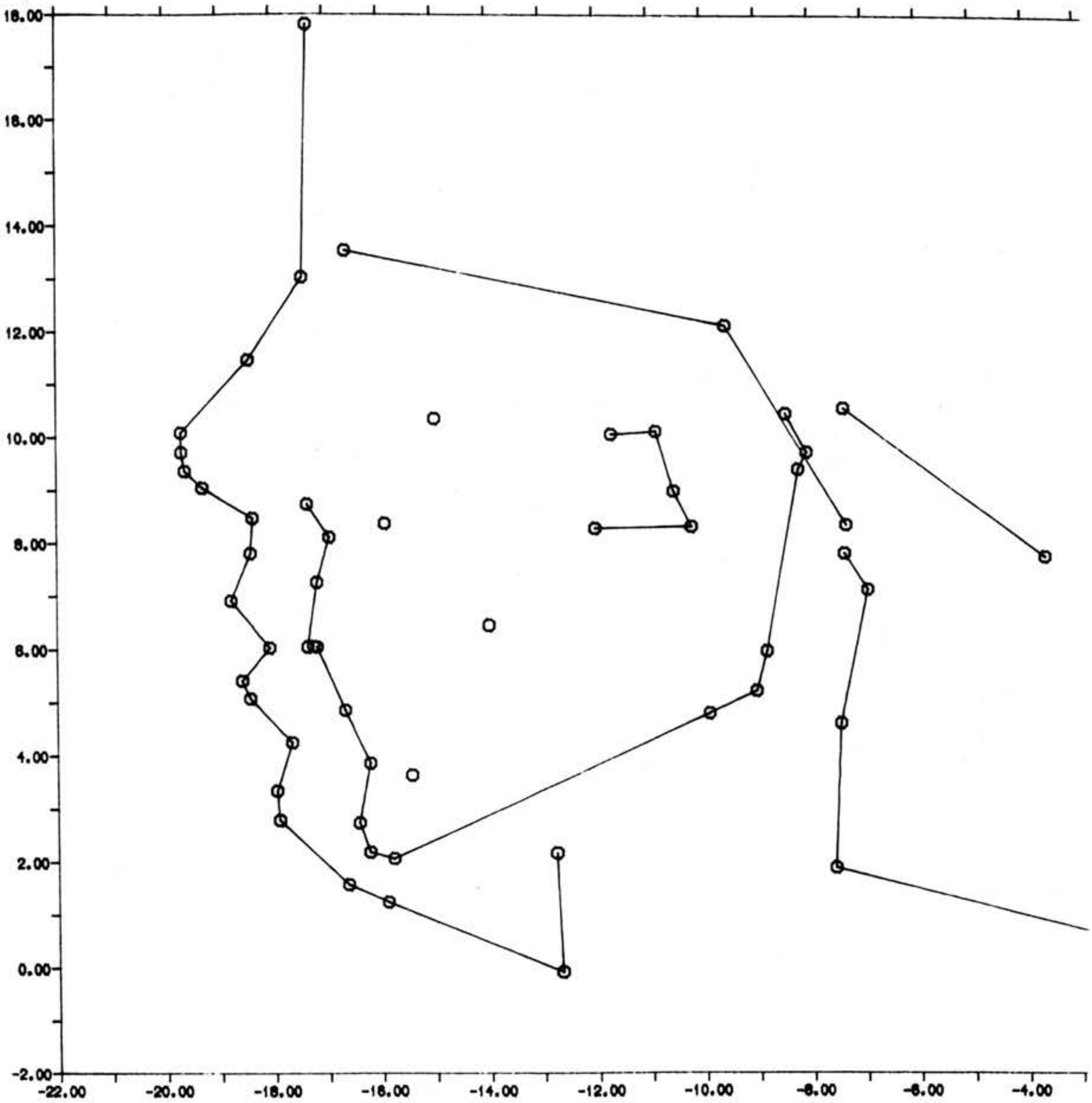
To reduce the radiation dosage to the patient, lead aprons were worn; the rare earth intensifying screens (Trimax T16) were installed in the cassette and high speed film was used (Trimax XD). A grid to enhance image quality was attached to the cassette which had incorporated into it 70 absorbing strips per cm. (Fig. 10. A vertical silver plumbline 1.5 mm in diameter was suspended at the occipital end of the film holder in order to indicate a true vertical (Figs. 2 & 10).

The resulting standardised cephalometric lateral skull radiograph with the subject in natural head posture is shown in Fig. 4. The vertical silver plumbline is seen distal to the occipital bone.

iii) Digitiser

Analysis of the lateral cephalometric radiographs was carried out by comparison and statistical assessment of computer filed co-ordinate data for 57 reproducible points (Fig. 12) or cephalometric landmarks on the radiographs, delineating 64 linear

Fig. 12 Pen plot from the 57 reproducible cephalometric points digitised from the lateral skull radiograph.



patient cont17

and angular variables (Table 5).

Each lateral cephalometric radiograph was traced on acetate tracing paper and the 57 reproducible points defined and numbered in an established sequence as defined for the study.

Computer programmes to record the X and Y co-ordinate position of each point were written for the project by the Edinburgh Regional Computing Centre (ERCC) as specified by the author.

Co-ordinate data collection was carried out with a Graf-Bar sonic digitiser (Fig. 13). Point reproducibility studies and linearity testing of the digitiser were carried out and are reported as part of the study (Section 5b).

A Graf-bar model GP-7 sonic digitiser was selected from a number of units commercially available. The dimension of the machine was 48 x 15 x 4.5 cm. This rectangular shape (Fig. 13) had advantages over the conventional 'L' shaped assembly because it allowed unhindered use of the illuminated viewing screen for radiographic digitising. The active area for digitising in front of the unit was 46 x 61 cm and the size of the radiographic film used in the study was 24 x 30 cm.

Fig. 13 Graf/Bar digitiser.


Graf/Bar
LINE
STREAM
CANCEL
POWER

TABLE 5

Variable descriptions

Variable number	Variable name	Variable parameters 1	2	3	4	5
1	n-s	11	10	0	0	0
2	n-sp	11	33	0	0	0
3	n-gn	11	24	0	0	0
4	s-ba	10	9	0	0	0
5	s-ar	10	20	0	0	0
6	s-pm	10	17	0	0	0
7	s-tg	10	22	0	0	0
8	sp-gn	33	24	0	0	0
9	ar-tgo	20	22	0	0	0
10	sp-pm	33	17	0	0	0
11	ss-pm	32	17	0	0	0
12	pgn-cd	25	18	0	0	0
13	pg-tgo	26	22	0	0	0
14	sp-is	33	30	0	0	0
15	ii-gn	29	24	0	0	0
16	n-s-ba	11	10	9	0	0
17	n-s-ar	11	10	20	0	0
18	pm-s-ba	17	10	9	0	0
19	s-n-sp	10	11	33	0	0
20	s-n-ss	10	11	32	0	0
21	s-n-sm	10	11	27	0	0
22	s-n-pg	10	11	26	0	0
23	ss-n-sm	32	11	27	11	0
24	ss-n-pg	32	11	26	11	0
25	NSL/NL	11	10	33	17	0
26	NSL/ML	11	10	24	23	0
27	NL/ML	33	17	24	23	0
28	NSL/MBL	11	10	25	18	0
29	ML/RL	19	21	24	23	0
30	IL_s/NL	30	34	17	33	0
31	ILi/ML	23	24	29	35	0

Table 5 (contd.)

Variable number	Variable name	Variable parameters 1	2	3	4	5
32	oj	30	37	0	0	5
33	ob	29	37	0	0	6
34	NSL/VER	11	10	1	2	0
35	NL/VER	33	17	1	2	0
36	NSL/OPT	11	10	4	5	0
37	NSL/CVT	11	10	3	5	0
38	NL/OPT	33	17	4	5	0
39	NL/CVT	33	17	3	5	0
40	OPT/HOR	4	5	1	2	3
41	CVT/HOR	3	5	1	2	3
42	FH/VER	12	8	1	2	0
43	FH/OPT	12	8	4	5	0
44	FH/CVT	12	8	3	5	0
45	$pm\text{-}ad_1$	17	16	0	0	0
46	$pm\text{-}ad_2$	17	15	0	0	0
47	$pm\text{-}ad_3$	17	14	0	0	0
48	$tu\text{-}ad_3$	13	14	0	0	0
49	$n_s\text{-}sn$	39	45	0	0	0
50	$n_s\text{-}prn$	39	42	0	0	0
51	lnt to n-ss	39	11	32	0	7
52	$s\text{-}n_s\text{-}unt$	10	39	41	0	0
53	sto to NL	48	33	17	0	7
54	$s\text{-}n_s\text{-}ss_s$	10	39	46	0	0
55	sn to $lnt\text{-}l_s$	45	43	47	0	7
56	ls to NCL	47	43	53	0	7
57	sto to ML	48	24	23	0	7
58	$s\text{-}n_s\text{-}sm_s$	10	39	51	0	0
59	sm_s to $li\text{-}pg_s$	51	49	52	0	7
60	li to NCL	49	43	53	0	7
61	$ss_s\text{-}n_s\text{-}sm_s$	46	39	51	39	0
62	sto to OL_s	48	30	36	0	7
63	$s\text{-}n_s\text{-}pg_s$	10	39	52	0	0
64	NFL/NCL	53	43	38	41	0

b) **Definitions of the Measurements**

The reference points defined and planes delineated on the cephalometric lateral skull radiographs are shown on Figs. 14, 15, 16, 17 & 18. The 57 points defined on the lateral skull radiograph of each patient enabled a detailed analysis of craniofacial form, head posture and airway to be carried out. The numeric cephalometric points and sequence used in the investigation are shown in Figs. 19, 20 &21. The variable descriptions of the linear and angular dimensions measured are shown in Table 5.

i) Reference points used in the study

ad_3 The point on the most anterior part of the adenoidal mass the shortest distance from the posterior wall of the maxillary antrum.

ad_2 The intersection of a line, with the adenoidal mass, drawn from pm to the midpoint of a line from s - ba.

ad_1 The intersection of a line, with the adenoidal area, drawn from pm to basion.

ai The apex of the root of the lower central incisor.

ar Articulare. The intersection between the external contour of the cranial base and the dorsal contour of the condylar head or neck.

as The apex of the root of the upper central incisor.

Fig. 14 Cephalometric points used in the study for head posture, airway and cranial base.

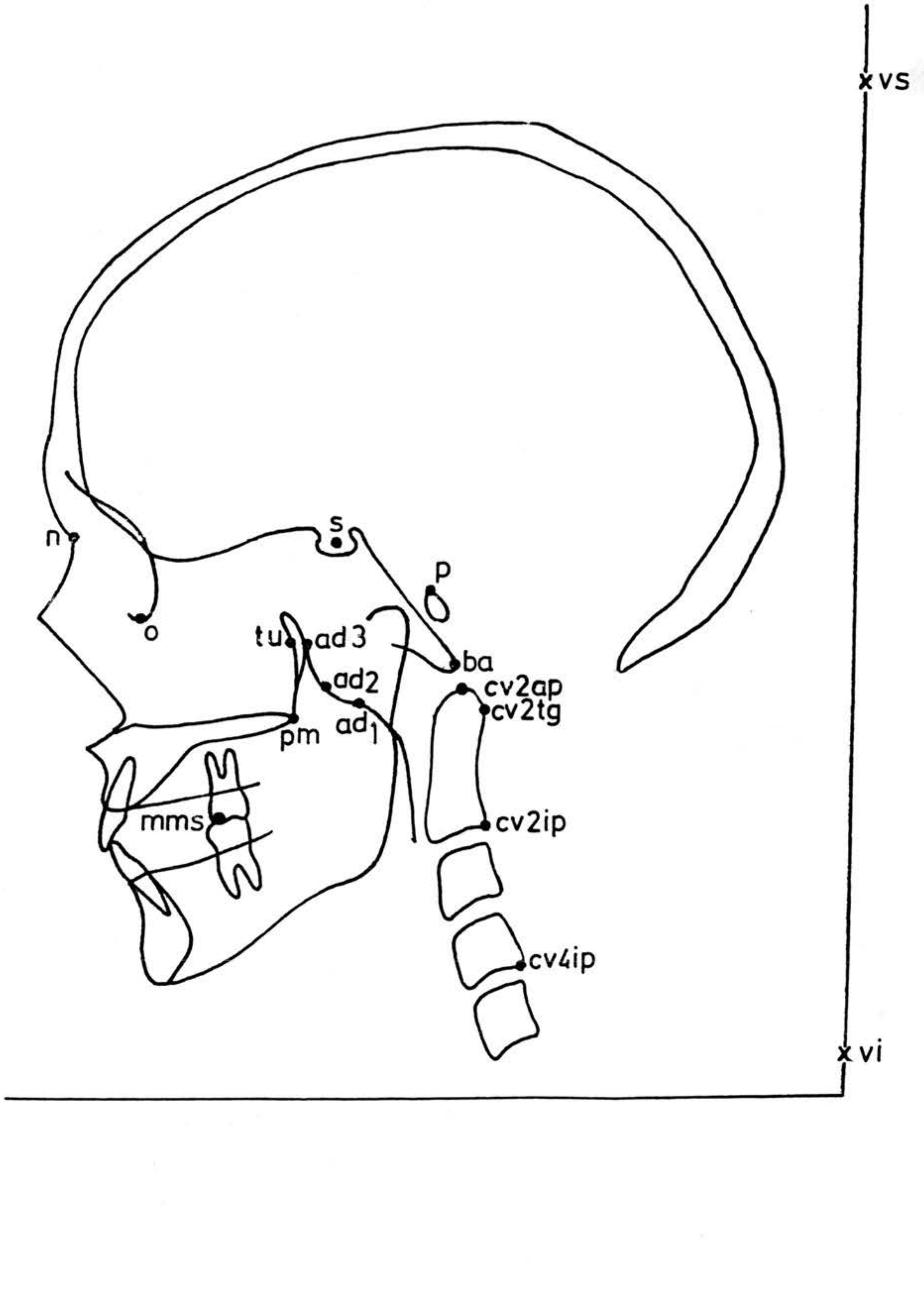
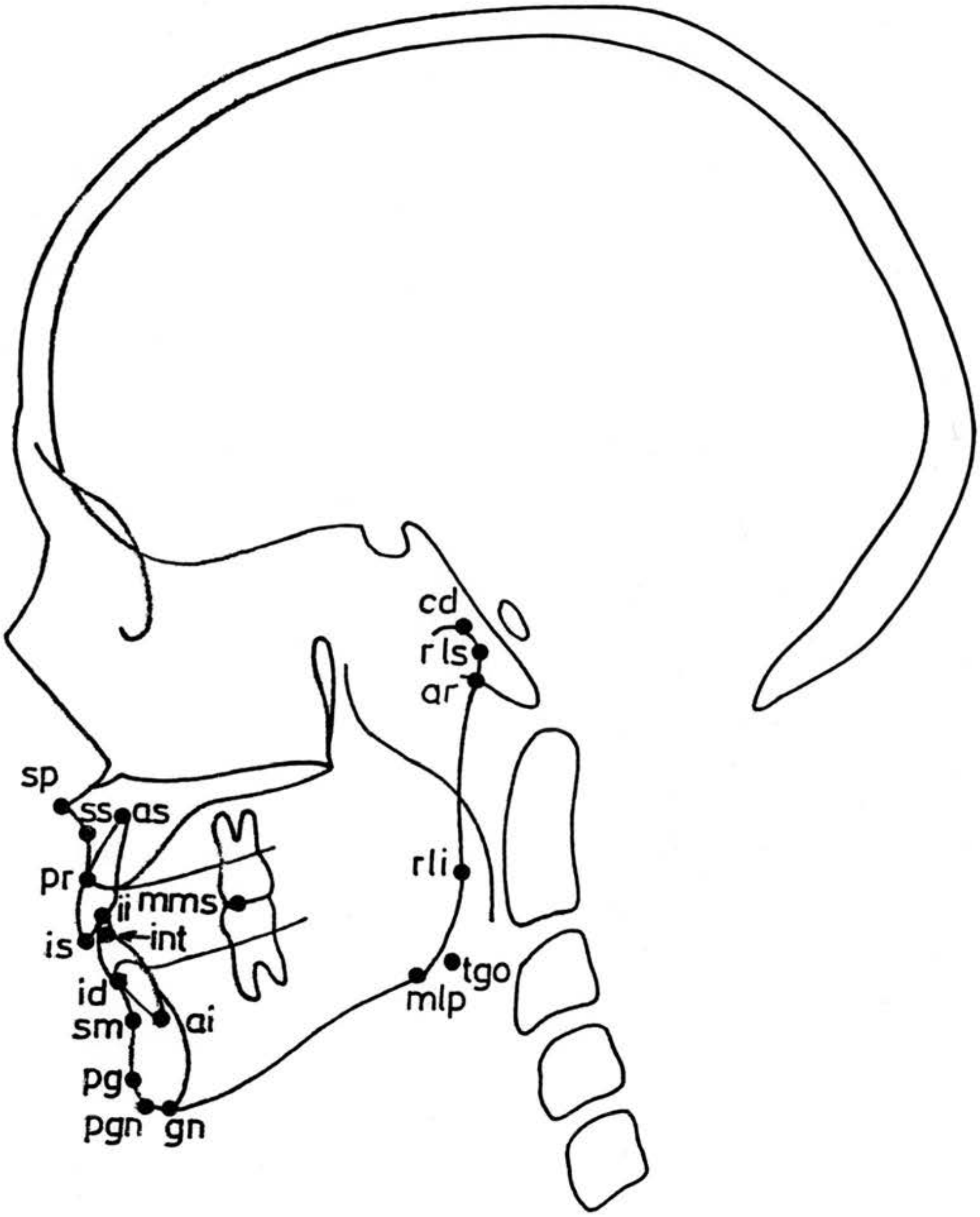
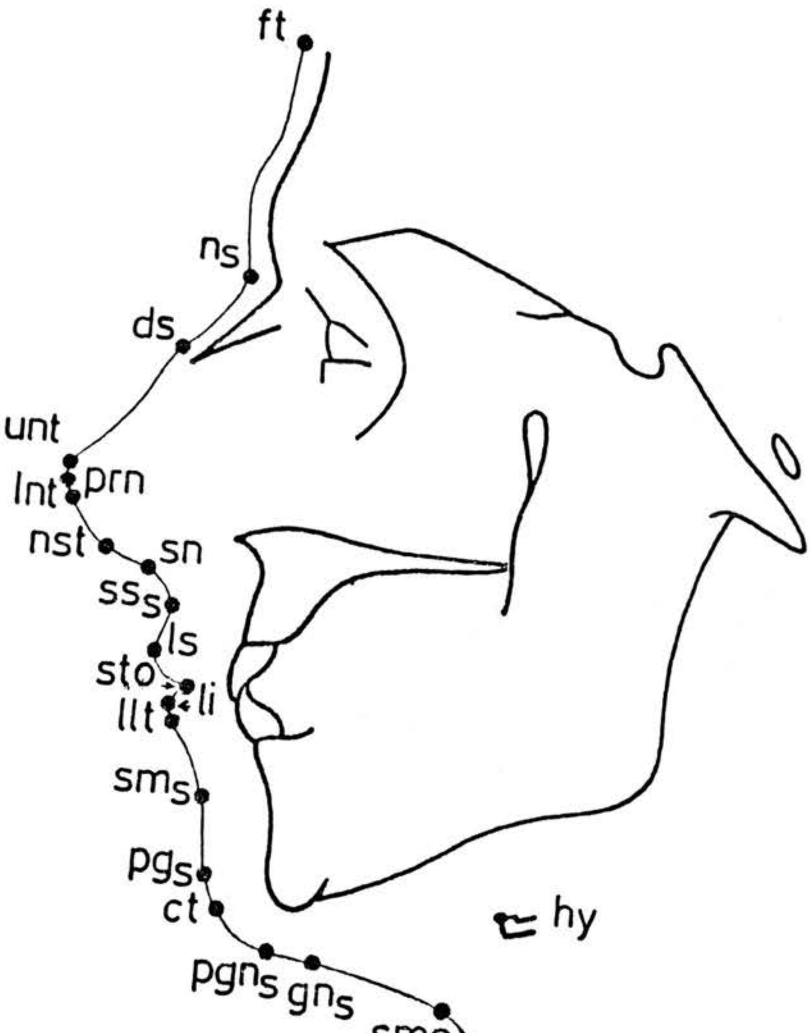

vs
s
n
p
o
tu
ad3
ba
ad2
cv2ap
cv2tg
pm
ad_1
mms
cv2ip
cv4ip
vi

Fig. 15 Cephalometric points used in the study for mandibular and dento-alveolar structures.



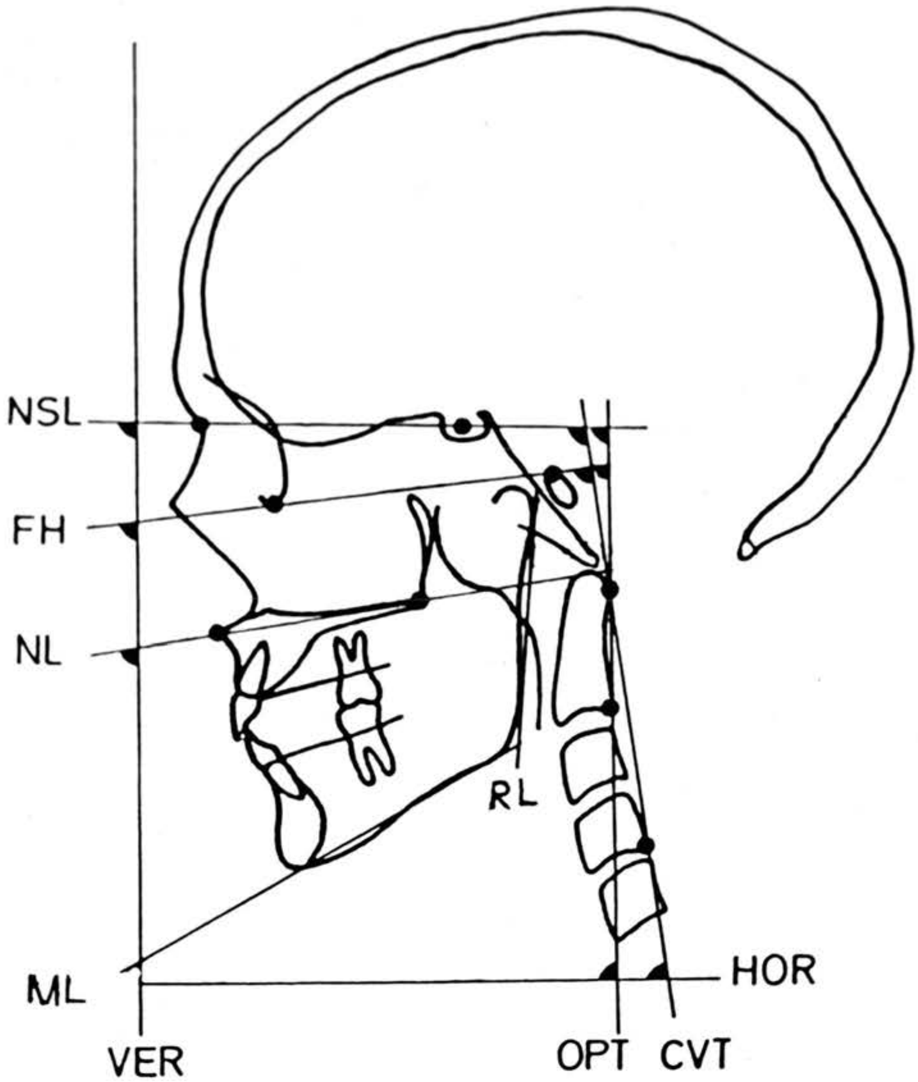
cd
r ls
ar
sp
ss
as
pr
ii
mms
is
int
rli
tgo
mlp
id
sm
ai
pg
pgn
gn

Fig. 16 Cephalometric points used in the study for soft tissue measurements.



ft
ns
ds
unt
prn
lnt
nst
sn
ss
ls
sto
li
llt
sm
pg
ct
pgn
gn
sme
hy

Fig. 17 Reference planes used in the study and angular head postural variables measured.


NSL
FH
NL
ML
RL
HOR
VER
OPT
CVT

ba Basion. The most postero-inferior point on the anterior margin of the foramen magnum.

cd Condylion. The most supero-posterior point on the condylar head.

ct Chin tangent point. The lower tangent point on the nose chin line.

cv2ap The apex of the odontoid process of the second cervical vertebra.

cv2tg The tangent point of OPT on the odontoid process of the second cervical vertebra.

cv2ip The most postero-inferior point on the corpus of the second cervical vertebra.

cv4ip The most postero-inferior point on the corpus of the fourth cervical vertebra.

ds Dorsum nasi. The point located at the greatest convexity or concavity of the dorsum nasi.

ft Frontal tangent point. The upper tangent point of the nose-frontal line.

gn Gnathion. The most inferior point on the mandibular symphysis.

gn_s Soft tissue gnathion. The soft tissue point overlying gn.

hy Hyoideum. The most antero-superior point of the corpus of the hyoid bone.

id Infradentale. The most antero-superior point on the lower alveolar margin.

ii Incision inferius. The midpoint of the incisal edge of the most prominent lower central incisor.

int Incision occlusale. The projection of ii on OLS.

i_s Incision superius. The midpoint of the incisal edge of the most prominent upper central incisor.

li Labrale inferius. The most prominent point on the prolabium of the lower lip.

lnt Lower nasal tangent point. The upper tangent point of the nose-chin line.

llt Lower lip tangent point. The upper tangent point of the tangent to the lower lip through sms.

ls Labrale superius. The most prominent point on the prolabium of the upper lip.

mlp The posterior tangent point of ML.

mm_s The most inferior point on the mesio-buccal cusp of the upper first permanent molar.

n Nasion. The most anterior point of front-nasal curvature.

n_s Soft tissue nasion. The deepest point in the fronto-nasal curvature.

nst Nasal septum tangent point. The anterior tangent point of the tangent to the nasal septum through sn.

o Orbitale. The deepest point of the infra-orbital margin.

op Opisthion. The most antero-inferior point on the posterior margin of foramen magnum.

p Porion. The upper border of the bony external auditory meatus.

pg Pogonion. The most anterior point on the mandibular symphysis.

pgn Prognathion. The point on the mandibular symphysis farthest from cd.

pgn_s Soft tissue prognathion. The soft tissue point overlying pgn.

pg_s Soft tissue pogonion. The most prominent point on the chin.

pm Pterygomaxillare. The intersection between the nasal floor and the posterior contour of the maxilla.

pr Prosthion. The most antero-inferior point on the upper alveolar margin.

prn Pronasale. The most prominent point on the apex of the nose.

rli The lower tangent point of RL.

rls The upper tangent point of RL.

s Sella. The centre of sella turcica. The upper limit of the sella turcica is defined as the line joining the tuberculum and dorsum sellae.

sm Supramentale. The most posterior point on the anterior contour of the lower alveolar process.

sme Submentale. The deepest point in the submental-neck curvature.

sm_s Soft tissue supramentale. The deepest point in the mento-labial sulcus.

sn Subnasale. The deepest point in the naso-labial curvature.

sp Spinal point. The apex of the anterior nasal spine.

ss Subspinale. The most posterior point on the anterior contour of the upper alveolar process.

ss_s Soft tissue subspinale. The most dorsal point on the upper lip overlying ss.

sto Stomion. The deepest point in the rima oris.

tu Tuber. The most posterior point on the maxillary tuberosity the shortest distance from ad_3.

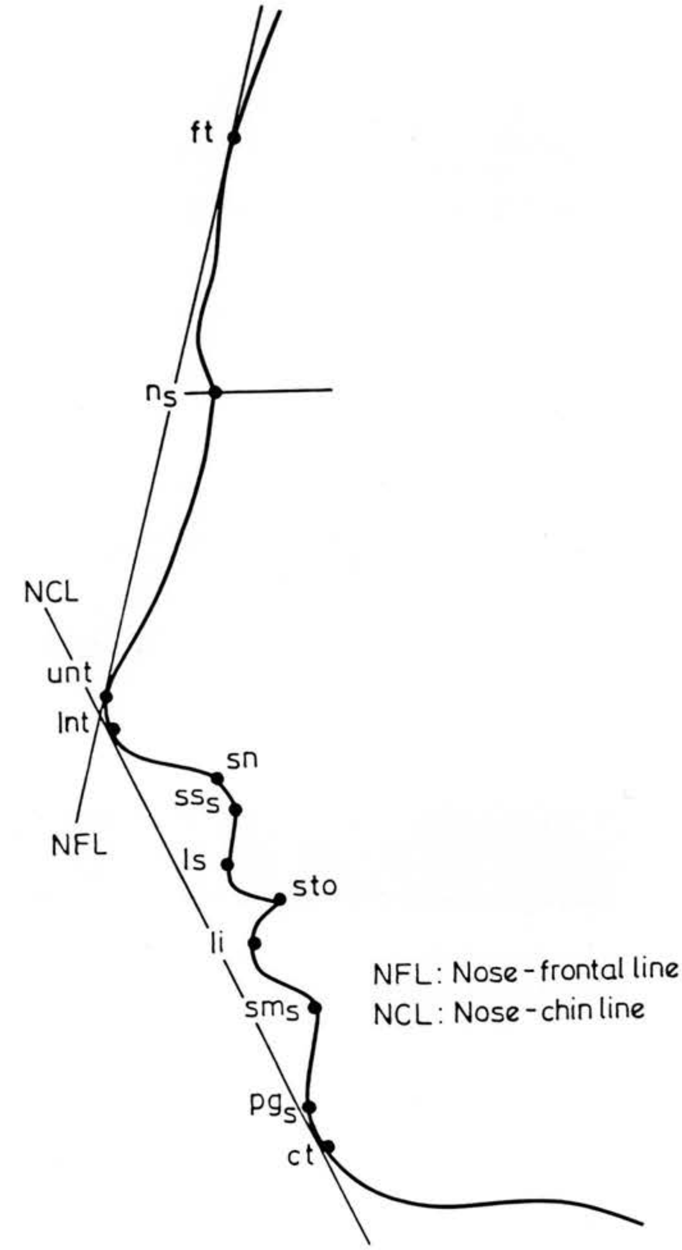
tgo The point of intersection between ML and RL.

unt The upper nasal tangent point. The nasal tangent point of the nose-frontal line.

vi The lower point on the vertical line.

vs The upper point on the vertical line.

Fig. 18 Soft tissue reference planes used in the study.


ft
n_s
NCL
unt
lnt
sn
ss_s
NFL
ls
sto
li
sm_s
pg_s
ct
NFL: Nose-frontal line
NCL: Nose-chin line

ii) Reference lines used in the study

CVT Cervical vertebrae tangent. The posterior tangent to the odontoid process through cv4ip.

FH Frankfort horizontal line. The line drawn from orbitale to porion.

HOR True horizontal line. The line perpendicular to VER.

ob Overbite. A linear measurement of the distance the upper central incisor overlaps the most prominent lower incisor measured from ii to int.

oj Overjet. A linear dimension of the protrusion of the upper central incisor measured from is to int.

NCL Soft tissue nose chin line. A line through lnt and ct.

NFL Soft tissue nose frontal line. The line through ft and un.

MBL Mandibular base line. The line through pgn and cd.

ML Mandibular line. The tangent to the lower border of the mandible through gn.

NL Nasal line. The line through sp and pm.

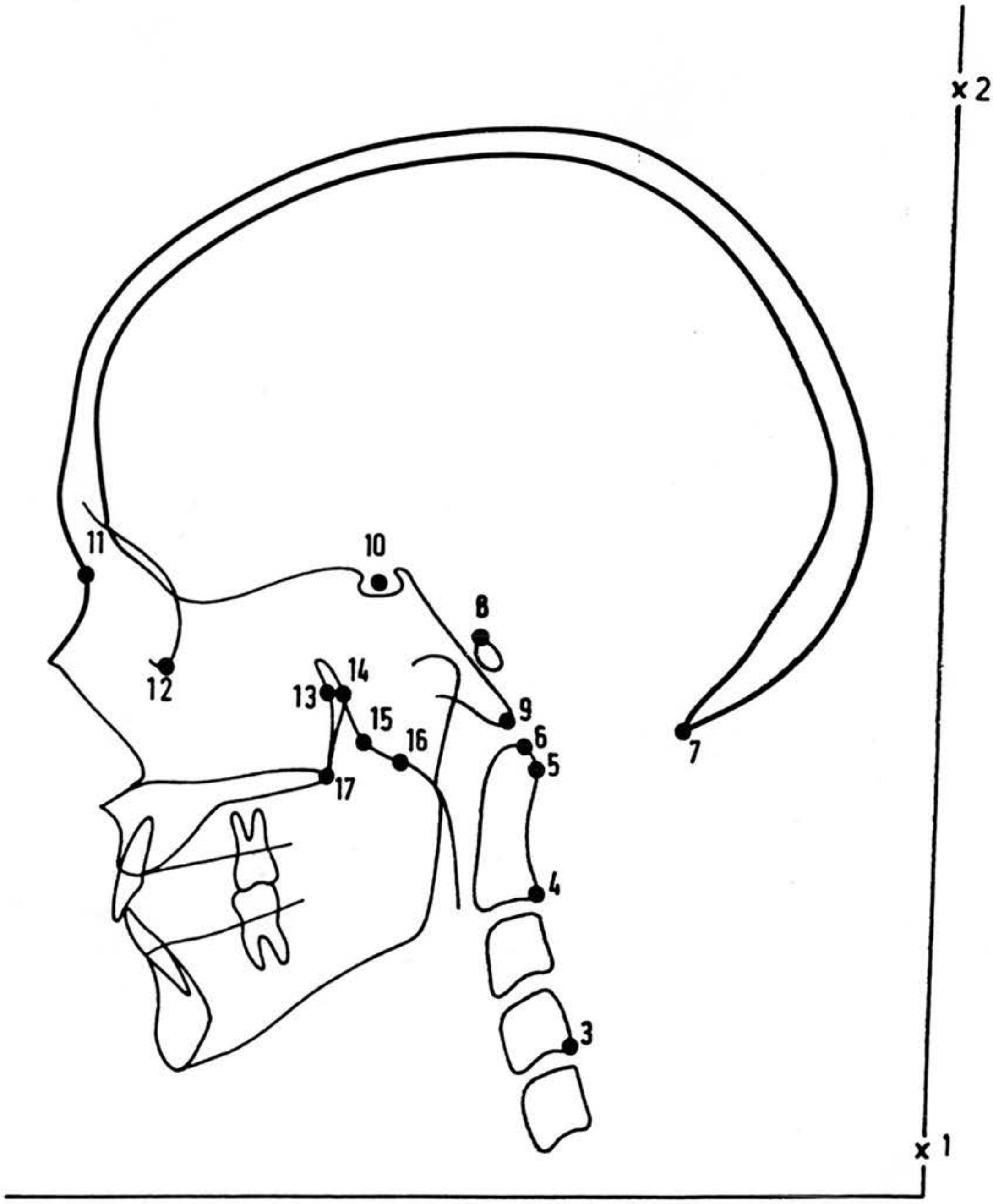
NSL Nasion-sella line. The line through n and s.

OPT Odontoid process tangent. The posterior tangent to the odontoid process through cv2ip.

RL Ramus line. The tangent to the posterior border of the mandible.

VER True vertical line projected on the film.

Fig. 19 Numbered cephalometric points for head posture, airway and cranial base used in the study.


x 2
10
11
8
12
13
14
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15
16
6
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17
7
4
3
x 1

Fig. 20 Numbered cephalometric points for mandibular and dento-alveolar structures used in the study.

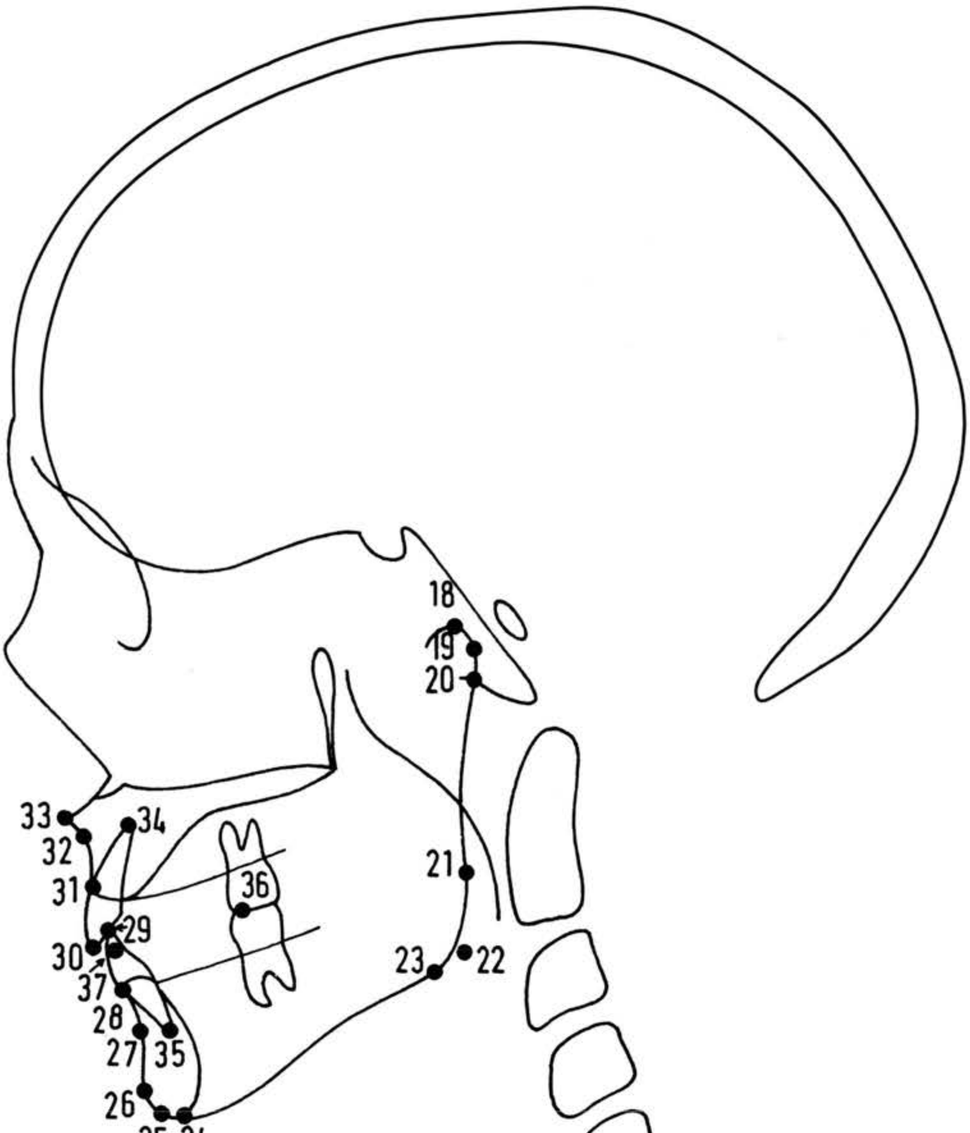
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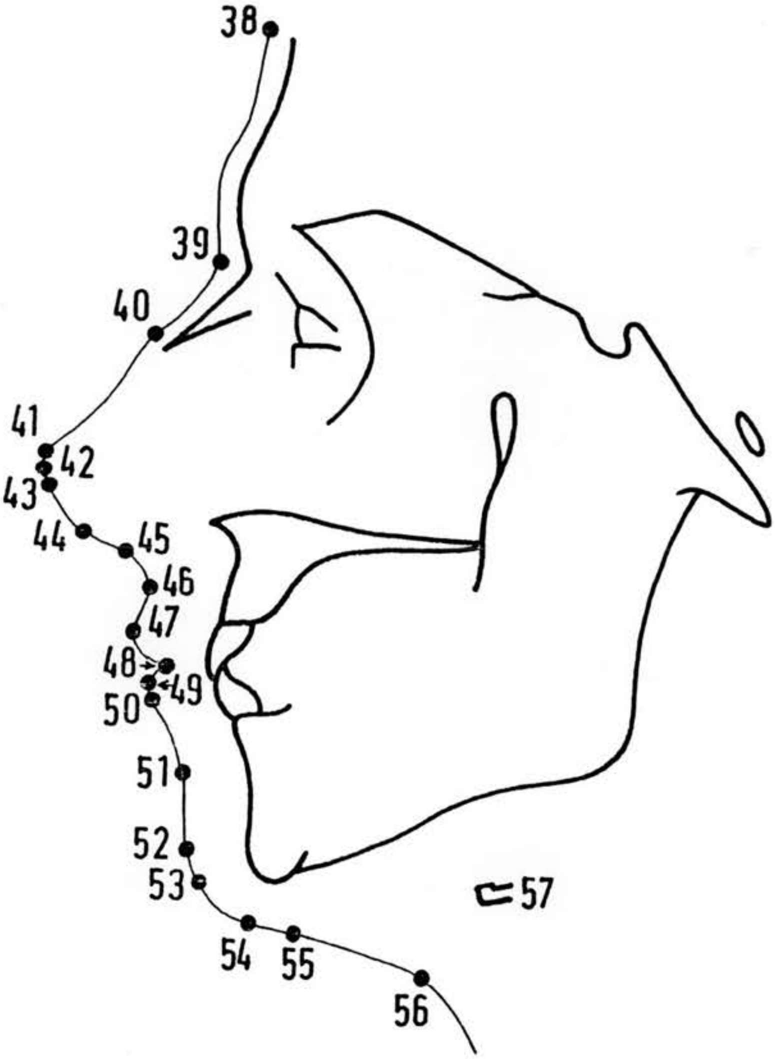
Fig. 21 Numbered cephalometric points for soft tissue used in the study.


38
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56
57

iii) Radiographic cephalometric measurements

a) Linear dimensions:

1. n-s
2. n-sp
3. n-gn
4. s-ba
5. s-ar
6. s-pm
7. s-tgo
8. sp-gn
9. ar-tgo
10. sp-pm
11. ss-pm
12. pgn-cd
13. pg-tgo
14. sp-is
15. ii-gn

b) Angular dimensions

16. n-s-ba
17. n-s-ar
18. pm-s-ba
19. s-n-sp
20. s-n-ss
21. s-n-sm
22. s-n-pg
23. ss-n-sm
24. ss-n-pg

25. NSL/NL

26. NSL/ML

27. NL/ML

28. NSL/MBL

29. ML/RL

c) Dento-alveolar relations:

30. IL_s/NL

31. IL_i/ML

32. oj/ (mm)

33. ob (mm)

d) Head posture:

34. NSL/VER

35. NL/VER

36. NSL/OPT

37. NSL/CVT

38. NL/OPT

39. NL/CVT

40. OPT/HOR

41. CVT/HOR

42. FH/VERT

43. FH/OPT

44. FH/CVT

e) Airway:

45. $pm\text{-}ad_1$

46. $pm\text{-}ad_2$

47. $pm\text{-}ad_3$

48. $tu\text{-}ad_3$

f) Soft tissue:

49. $n_s\text{-}sn$

50. $n_s\text{-}prn$

51. lnt to n-ss

52. $s\text{-}n_s\text{-}unt$

53. sto to NL

54. $s\text{-}n_s\text{-}ss_s$

55. sn to $lnt\text{-}l_s$

56. l_s to NCL

57. sto to ML

58. $s\text{-}n_s\text{-}sm_s$

59. sm_s to $li\text{-}pg_s$

60. li-NCL

61. $ss_s\text{-}n_s\text{-}sm_s$

62. sto to OL_s

63. $s\text{-}n_s\text{-}pg_s$

64. NFL/NCL

g) Nasal respiratory resistance measured for inspiration(i) and expiration(e) in Pascals/cc/sec x 10^3.

NRR Nasal respiratory resistance.

PNR Bilateral nasal respiratory resistance (posterior method).

ANR Unilateral nasal respiratory resistance (anterior method).

c) **Clinical procedures**

i) Rhinomanometric

Rhinomanometry is a procedure used to measure the resistance to airflow through the nasopharyngeal airway. The procedure is based on simultaneous recording of airflow through the nose together with pressure difference between external and internal opening of the nasal cavity during respiration.

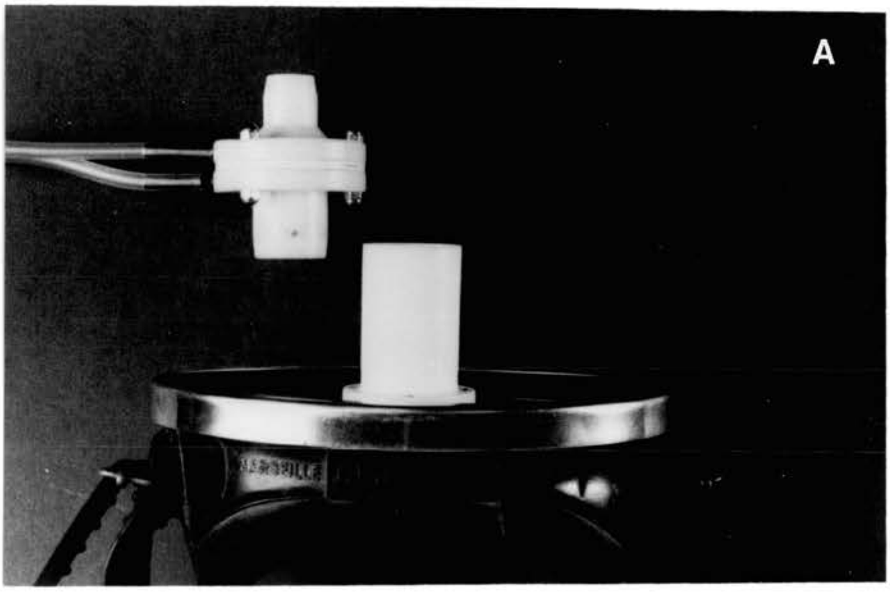
Posterior method (bilateral measurements)

The airflow was recorded by a pneumotachograph fitted into a mask which is placed over the nose (Fig. 22). The pressure difference between the nares and choanae can be recorded in two ways. In posterior rhinomanometry the subject holds a tube in the mouth which records pressure in the oral cavity, and thus the pressure behind both choanae (Solow & Greve 1980) (Figs. 23 & 24). The pressure outside the nares is taken from the proximal side of the pneumotachograph.

Fig. 22 Mask used in the study.

A Pneumotachograph and face mask attachment.

B Pneumotachograph inserted into the face mask attachment.


A

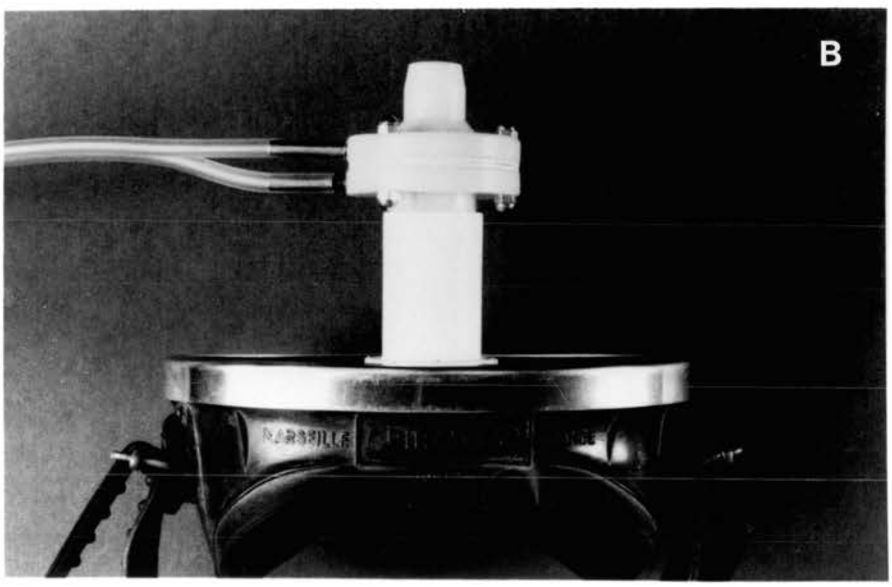

B

Fig. 23

Large diameter tube with otoscope tip which is inserted into the oral cavity for recording of bilateral nasal respiratory resistance (posterior method).

Illustration shows:

A The modified otoscope tip slid over the tube together with

B The connector attachment.

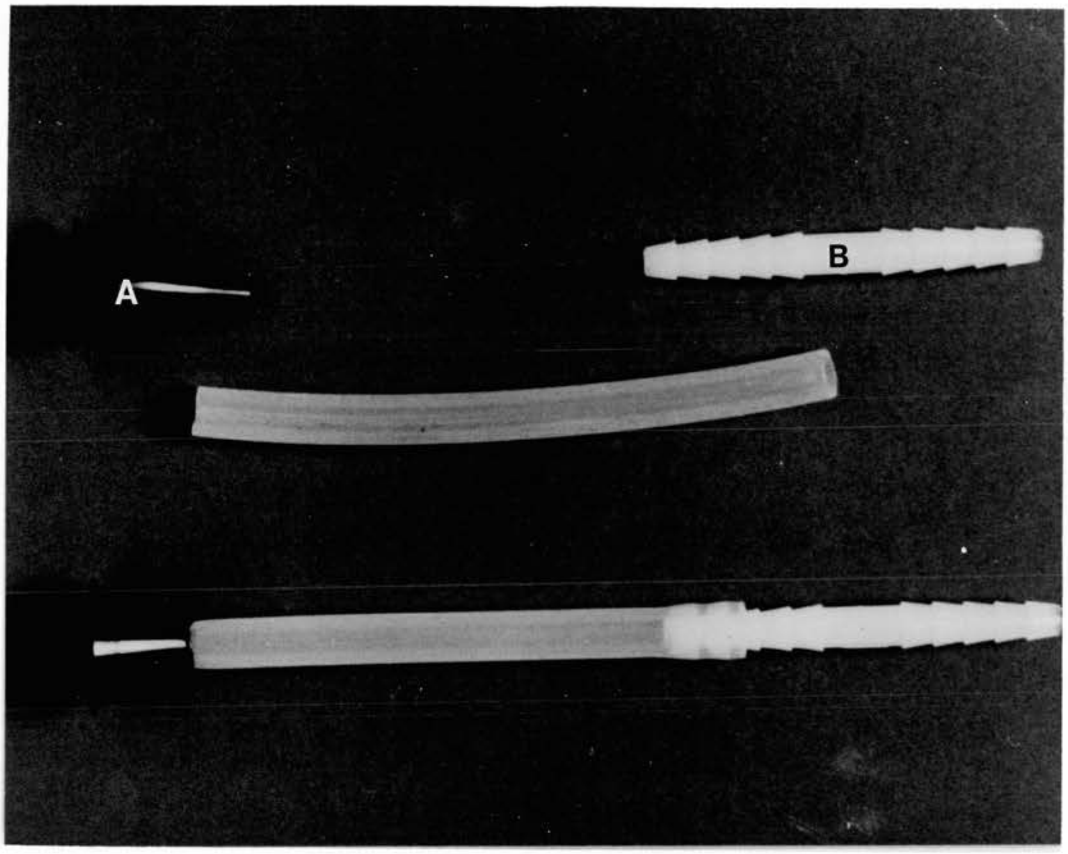
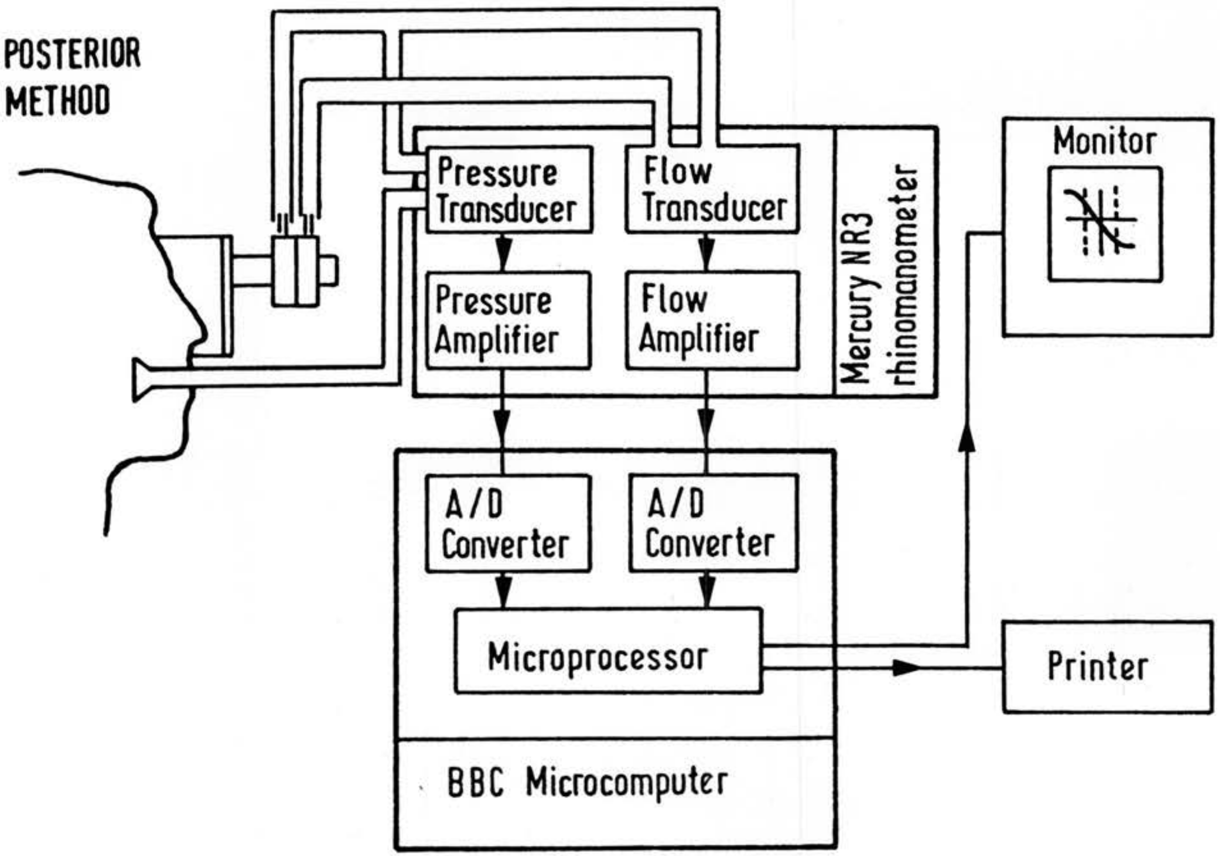

A
B

Fig. 24 Schematic drawing of the interelationships of the computerised rhinomanometry system set for recording bilateral nasal respiratory resistance, (posterior method).

POSTERIOR
METHOD



Anterior method (unilateral measurements)

In anterior rhinomanometry the resistance of the two nasal halves is recorded separately. A thin tube is fixed airtight to one nostril (Figs. 25 & 26). Via this nasal tube the pressure behind the opposite nasal half is recorded. The pressure outside the nostril is recorded as in the posterior method from the proximal side of the pneumotachograph. The procedure is performed separately for each nasal half.

A number of methological choices have to be made in the clinical set-up for rhinomanometry:-

1. A decision must be made as to whether the recording is to be made with or without the use of a nasal decongestant, such as xylometazoline hydrochloride.

2. A decision must be made regarding the use of anterior, posterior or both types of method.

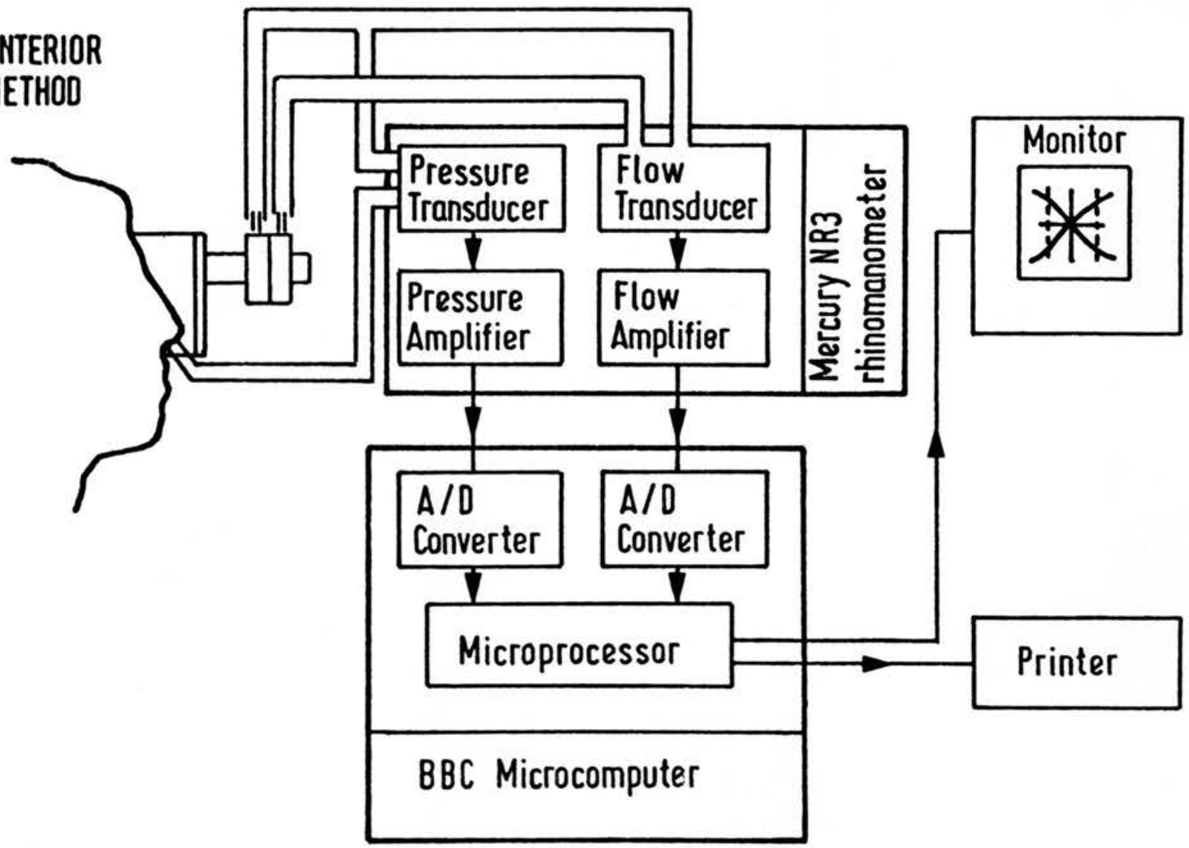
3. A decision must be made regarding the flow or pressure threshold to be used.

Due to the changing combination of laminar and turbulent air flow, resistance changes continuously during the respiratory cycle (Jonson et al 1983; Hudgel & Robertson 1984). In order to obtain comparable measurements, it was agreed at an international meeting on rhinomanometry (Clement 1984) that the nasal respiratory resistance should be reported for the moment in the respiratory

Fig. 25 Recording of unilateral nasal respiratory resistance, (anterior method).

Fig. 26 Schematic drawing of the interelationships of the computerised rhinomanometry system set for recording unilateral nasal respiratory resistance, (anterior method).

ANTERIOR
METHOD



cycle when a pressure difference has attained a value of 150 Pascals. Since airflow and turbulence increase with increasing pressure differences, the resistance will in general be higher at pressure differences exceeding the standard threshold value of 150 Pascals. Methods for recording separately the laminar and turbulent components of a subject's nasal resistance have been described but have so far not been made available commercially (Hansen et al 1984).

Nasal resistance was recorded by a Mercury rhinomanometer NR3 computerised system (Fig. 25). The pressure differentials recorded by the pneumotachograph and the pressure recording tubes are converted to electrical currents by pressure transducers in the rhinomanometer (Figs. 24 & 26). Such devices may respond differently under static and dynamic loads, such as that occurring during respiration. They may also change due to temperature gradients. Frequent calibration under dynamic conditions is therefore essential for reproducible recordings.

The rhinomanometer was calibrated at the start of each recording session with a Mercury FP1 calibration unit producing dynamic pressure and flow signals, peaking for pressure at 500 Pascals, and for flow at 150 cc/sec (Fig. 3). Threshold limits of 500 Pascals for pressure (Fig. 27) and 150 cc/sec for flow (Fig. 28) were established on the rhinomanometer. The curve produced from the pressure and flow signals generated by the calibration unit was adjusted to peak to the defined threshold limits visible on the screen (Figs. 27 & 28).

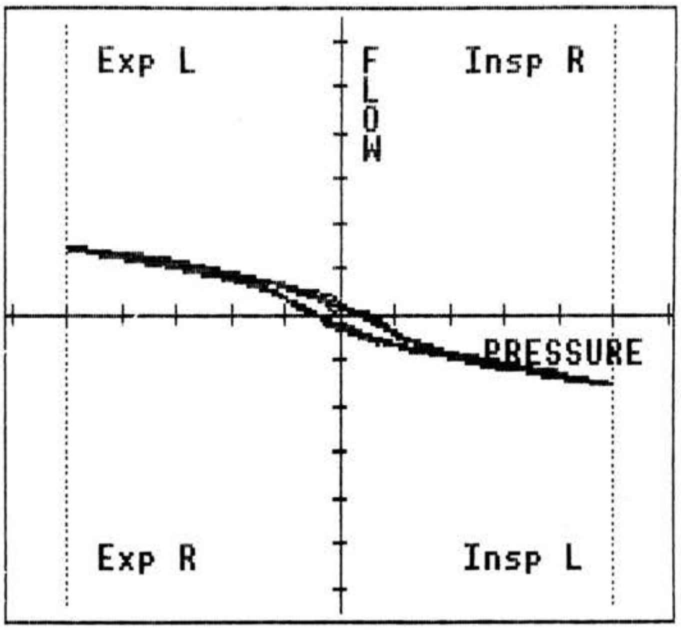
Each subject was administered 0.1% xylometazoline hydrochloride as a nasal spray in each nostril half an hour before each recording session.

Measurements of nasal resistance were made unilaterally for the right and left sides by the anterior method (Fig. 29), as well as bilaterally by the posterior method as described by Solow & Greve (1980). However, instead of the individually lined mask suggested by Solow & Greve (1980), a scuba diving mask covering nose and eyes was used as recommended by Hansen _et al_ (1984). A hole was made in the screen of the mask and a connector, for the pneumotachograph, was fitted to it.

For fixation of the pressure recording tube for the anterior method, a modification of the adhesive tape technique developed by Broms _et al_ (1982a) (Fig. 29 A) was used. A hole was punched in the Leukoflex adhesive tape (Fig. 30) and a flanged connector was pushed through from the nasal side into a short retaining tube into which the pressure recording tube was fixed (Fig. 29 B).

For the pressure recording by the posterior method, the large diameter tubing and the bio-feedback technique described by Solow & Greve (1980) was used (Fig. 23). With this technique, recordings

Fig. 27 Calibration curve for pressure produced on the monitor and peaking at pre-set threshold limits of $\pm$ 500 Pascals.



Exp L
FLOW
Insp R
PRESSURE
Exp R
Insp L

Fig. 28 Calibration curve for flow produced on the monitor and peaking at pre-set threshold limits of $\pm$ 150 cc/sec.

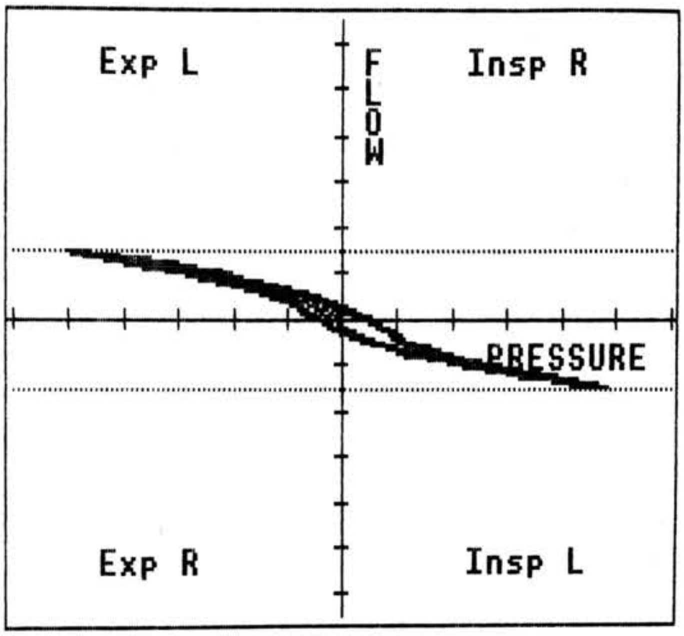

Exp L
Insp R
FLOW
PRESSURE
Exp R
Insp L

Fig. 29

A. Small diameter pressure recording tube attached to the nasal aperture by adhesive tape for recording unilateral nasal resistance by the anterior method.

B. Flange connector '1' is pushed through a hole punched in an adhesive square from the nasal side into a short retaining tube '2' which produces a seal. The attachment can be left fixed to the nasal aperture during a number of recordings. A simple connecting tube '3' can be slid in and out of the attachment as required.

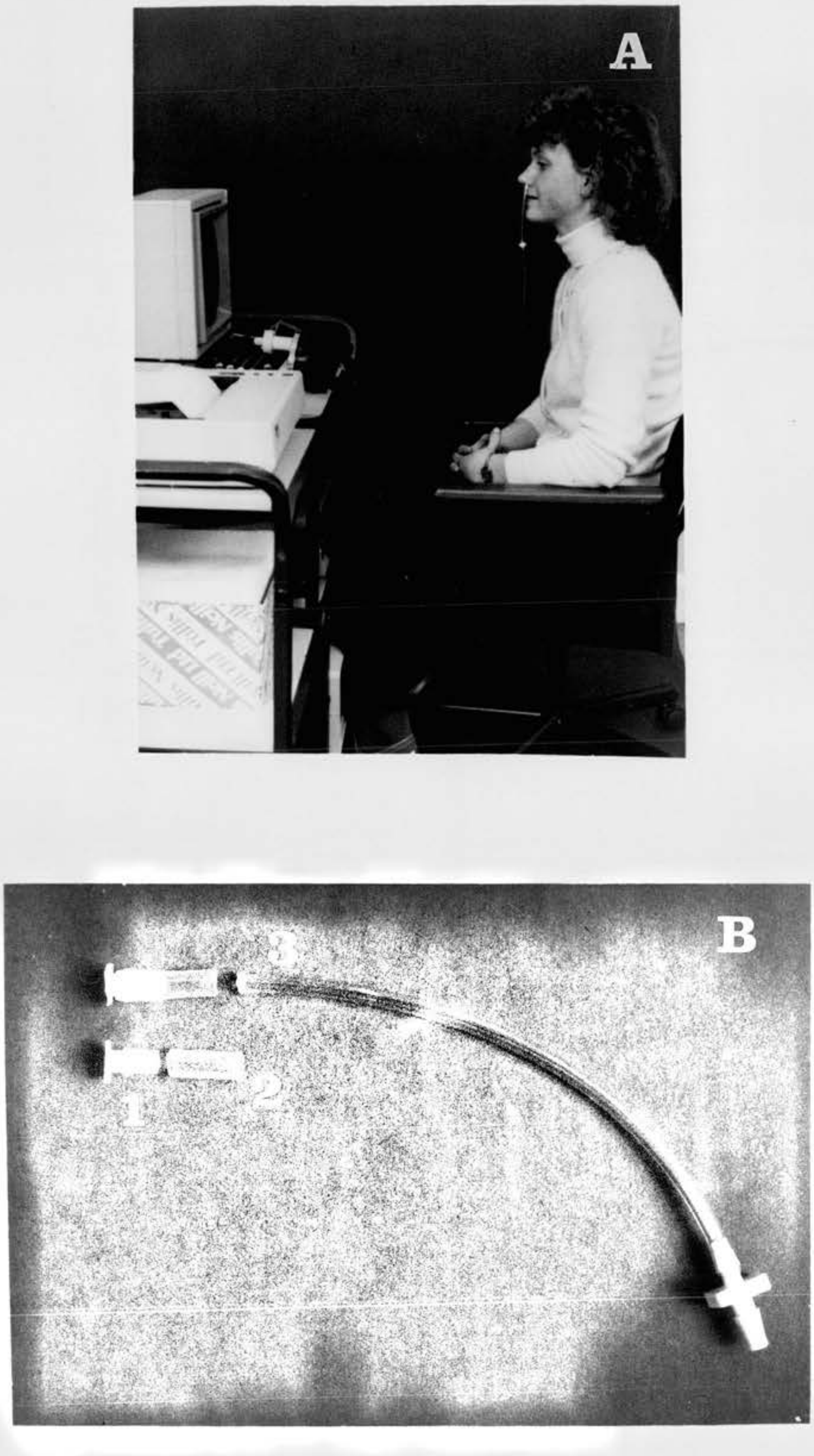

A
B
3
2
1

Fig. 30 Leukoflex adhesive tape for attachment of pressure tube to left or right nostril for measurements of unilateral nasal resistance (anterior method).


Leukoflex®
BDF
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could be made for all patients in the study with no failures being recorded, although two patients with a cold resulting in nasal congestion were removed from the control group.

All recordings were made at a fixed pressure of 150 Pascals. The mean of 16 recordings for each value of nasal resistance for both inspiration and expiration was used for further analysis.

The patient was seen on arrival and the nasal spray was placed in the left and right nostrils. This antihistamine spray eliminated the cyclic turbinate engorgement (Lenz et al 1985) and nasal congestion associated with infection or allergy, to establish a free airway (Henriksen & Wenzel 1984). The subject was instructed not to blow the nose for 5 minutes after the spray, but to sit quietly. Radiographs and subsequently rhinomanometric records for both the control group and cleft sample were then obtained.

The anterior unilateral records were obtained first and Fig. 29 A demonstrates the technique of application of the Leukoflex tape to the nostril. A piece of the adhesive tape was cut from the roll (Fig. 30) and a small hole punched in the centre with a card punch. The plastic insert was then pushed through from the adhesive side (Fig. 29 B). This had a flange on the adhesive side which aided the production of an airtight seal. A plastic collar cut from a length of polythene tube 3 mm long with an internal diameter of 1.5 mm was slid over the plastic insert as it emerged through the hole in the adhesive tape. By pressing the tube against the flange on the other side of the tape, an airtight seal was produced. The adhesive section was then placed over the nasal aperture (Broms _et al_ 1982a). The short length of tubing emerging from the tape was then used as a joint to which the pressure tube could be connected. Figure 29 B shows how this arrangement enabled easy assembly and connection of the pressure recording fine bore tube.

The nasal respiratory resistance for each half of the nose was recorded by sealing the pressure tube to the opposite nostril, the pressure recorded at the nasal aperture being equal to that behind the choanae.

The close fitting swimming mask covering nose and eyes and incorporating the pneumotachograph was placed on the face with the pressure recording tube emerging from the mask below the nostril to which the tube was attached (Fig. 26).

Measurements for inspiration and expiration were obtained, 16 recordings for each component of the respiratory cycle (Fig. 31). The adhesive tape was then removed and applied to the opposite nostril, a further 16 recordings being made.

Flow at a fixed pressure of 150 Pascals was recorded and this expressed in units of cc/sec, nasal respiratory resistance (NRR) being expressed in Pascals/cc/sec x 10^3.

Posterior measurements were then obtained, the pressure recording tube being inserted into the oropharynx to record pharyngeal pressure (Fig. 24). The tube inserted into the mouth was a 10 cm long x 3 mm internal diameter polythene tube, modified by an otoscope tip at the end to assist with correct soft palate position via a feedback mechanism. Visual feedback was obtained by patient observation of the trace on a monitor as the recording was in progress (Fig. 32). Posterior measurements can pose problems with patient co-operation as soft palate position is important when obtaining the records. Elevation of the palate to seal the nose produced oral airflow and increased pressure in the tube. The trace produced on the screen then became erratic. If this occurred, the recording was repeated. With practice and visual feedback, all patients in the study were able to have rhinomanometric records collected.

The nasal resistance meter (NR3) is based on a two membrane type differential pressure transducer, recorder and light beam deflection system. Elastic recoil in the transducers required electronic damping to reduce an inherent hysteresis in the system, this being most obvious with large and rapid respiratory excursions.

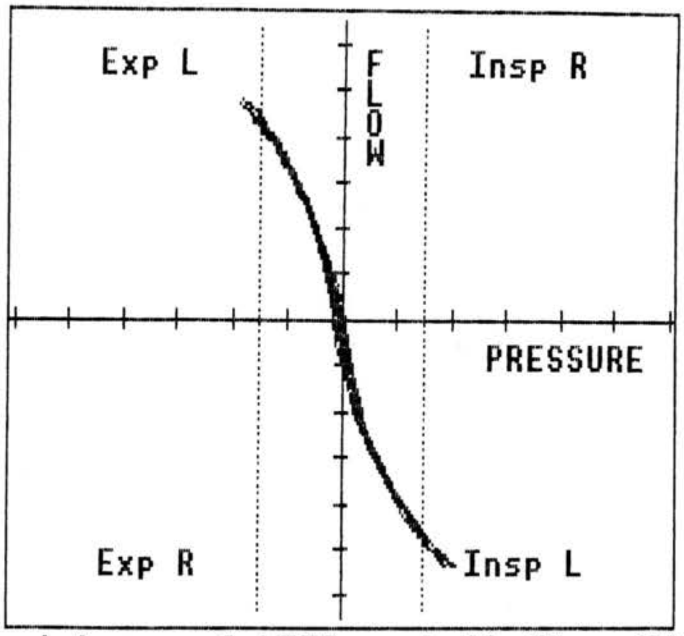
Recordings were made with slow near normal respiratory cycles, the patient being instructed to ensure that the depth of the expiration or inspiration was sufficient so the trace produced on

Fig. 31 Sigmoid curve produced during measurements of unilateral nasal respiratory resistance at pre-set pressure of 150 Pascals.

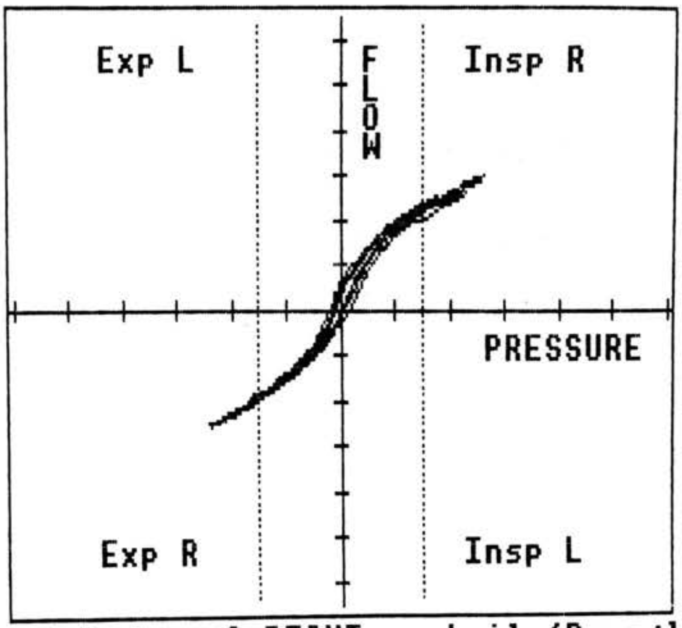
A. Left unilateral measurements.

B. Right unilateral measurements.

Note: Flat curve produced by higher unilateral right side nasal resistance.

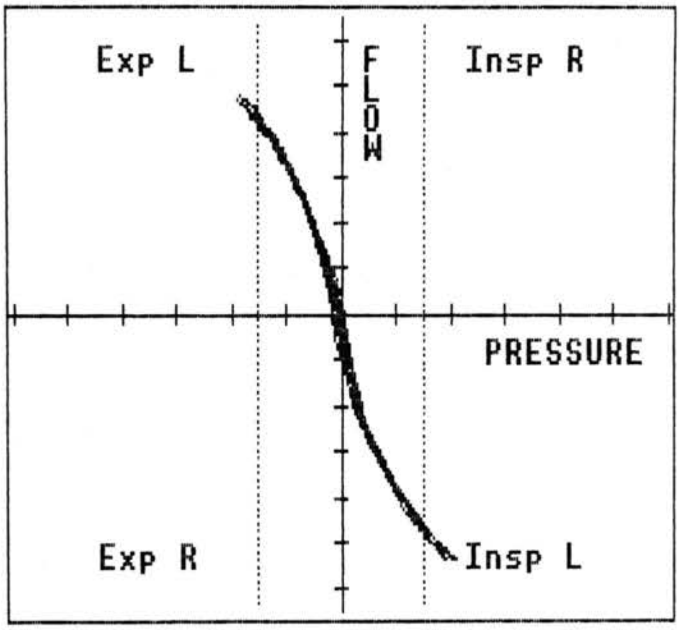


Resistance of LEFT nostril (Pa.s/l)



Resistance of RIGHT nostril (Pa.s/l)

Fig. 32 Sigmoid curve produced during measurements of bilateral nasal respiratory resistance. The calculation was made when the curve reached a pre-set pressure threshold of 150 Pascals.


Exp L
FLOW
Insp R
PRESSURE
Exp R
Insp L

the monitor crossed the marked threshold line. This was particularly important for the older patient in the study, because of naturally lower resistance values.

The posterior test was repeated to obtain 16 recordings for inspiration and expiration.

ii) Radiographic

For each subject in the control sample and the cleft group, a standardised lateral cephalometric radiograph was taken with the subject in natural head posture. The positioning for this method has been described by Solow & Tallgren (1971a, 1971b) and Siersbaek-Nielsen & Solow (1982) and consists of a rehearsal stage and a positioning stage:-

a) Rehearsal stage

Body posture and head position can be rehearsed before the patient is positioned in the cephalostat. Small children usually need no particular instruction about body posture, except that they should place the heels together and let the arms hang loosely at the side. Older patients should be told to walk on the spot and raise and lower the shoulders several times to relax.

Natural head position is the subject's own feeling of natural balance and is sometimes called the self-balance position. It is achieved by letting the patient tilt the head backwards and forwards with decreasing amplitude to find the most relaxed position. Once this position has been achieved the patient is asked to use an external reference source and look into their own eyes in a mirror placed at least 2 m away. This final adjustment is called the mirror position and is obtained after the self balance position has been achieved.

b) Positioning stage

The patient was slowly walked into the cephalostat which was lowered to check the ear rod position. If the ear rods were in front or behind the ears, the operator did not move the head as this would change the cranio-cervical angle. The operator's foot was placed in front or behind the patient's feet and the subject was asked to move slightly backwards or forwards, as the case required, until the shoes of the operator touched the subject's shoes in the required position in the cephalostat. Body position was established first, followed by the self balance head position. Finally, the patient was instructed to look into his own eyes in the mirror on the distant wall (Fig. 9).

No other external reference lines or means of support were used apart from the ear rods of the cephalostat. The patient was asked to remain still and relaxed with the teeth occluded in the correct bite while the film was exposed.

A silver plumbline was suspended over the cassette holder in the occipital region to mark the true vertical on the exposed film.

This technique was tested for reproducibility as part of the present investigation.

d) **Statistical Parameters**

For analysis of the data the following formulae were used:-

$\bar{x}$	arithmetical mean	$\frac{\Sigma x}{N}$
s	standard deviation	$\sqrt{\frac{\Sigma(x - \bar{x})^2}{N - 1}}$
s^2	variance	$\frac{\Sigma(x - \bar{x})^2}{N - 1}$
$s(\bar{x})$	standard error of the mean	$\frac{s}{\sqrt{N}}$
V	variation coefficient	$\frac{s}{\bar{x}} \times 100$
$\sqrt{b1}$	skewness	$\sqrt{\frac{N[\Sigma(x - \bar{x})^3]^2}{[\Sigma(x - \bar{x})^2]^3}}$
b2	kurtosis	$\frac{N\ \Sigma(x - \bar{x})^4}{[\Sigma(x - \bar{x})^2]^2}$
a	Geary's test	$\frac{\Sigma[x - \bar{x}]}{\sqrt{N\ \Sigma(x - \bar{x})^2}}$
F	variance ratio	$\frac{s^2\ max}{s^2\ min}$
t	students test	1) $\frac{\lvert\bar{x}_1 - \bar{x}_2\rvert}{\sqrt{\left(\frac{1}{N_1} + \frac{1}{N_2}\right)\frac{(N_1 - 1)\ s_1^2 + (N_2 - 1)s_2^2}{N_1 + N_2 - 2}}}$
		2) $\frac{\lvert\bar{x}_1 - \bar{x}_2\rvert}{\sqrt{\frac{s_1^2}{N_1} + \frac{s_2^2}{N_2}}}$

s(i) method error (Hald 1960) $\sqrt{\frac{\Sigma(x_1 - x_2)^2}{2N}}$

(%) experimental error (Trenouth *et al* 1985) $\frac{[s(i)]^2}{s^2} \times 100$

r correlation coefficient $\frac{\Sigma(x-\bar{x})\ \Sigma(y-\bar{y})}{\sqrt{\Sigma(x-\bar{x})^2\ \Sigma(y-\bar{y})^2}}$

SPSS — X

Statistical Package for the Social Sciences — X

CHAPTER 5

METHOD ERROR TESTS

a) Head Posture Variables

In order to assess the error of the method for head posture variability in standardised lateral cephalometric radiographs, 12 subjects (8 male and 4 female) aged between 8 years to 15 years from the control group had duplicate lateral skull films taken.

Repeat films were taken only after the original was identified as being of unsatisfactory image quality, to avoid unnecessary exposure to ionising radiation for non-therapeutic purposes. Scrutiny of the initial radiograph was carried out by the author and repeat films were required for over-exposure of soft tissue, incorrect occlusal registration and missed cranial structures. There was therefore a time lapse of at least one hour between the first and second film during which time rhinomanometric measurements were obtained. No repeat films for incorrect head posture or missed cervical vertebral components were included in the duplicate determination.

The same radiographer carried out all the film exposures for the study. The total control sample used in the study was accumulated over a period of eight months. The duplicate determinations were assembled from the control sample.

The positioning technique for the lateral cephalometric view of the cranio-cervical structures has been described by Solow & Tallgren (1971a, 1971b) and this method was used in the present study.

The cephalometric points were marked on acetate tracing paper placed over the radiographs on an illuminated viewing box with a fine hard (5H) drawing pencil. Angles were measured with a 25 cm diameter protractor to the nearest 0.1 of a degree.

The variables recorded were :-

NSL/VER°

NSL/OPT°

NSL/CVT°

OPT/HOR°

CVT/HOR°

OPT/CVT°

(Fig. 17)

Results

The first recordings of cranio-cervical postural angles are shown in Table 6. The second recordings from the second radiograph are shown in Table 7, and the differences between the first and second recordings are shown in Table 8.

The means, standard deviations and ranges for the postural angles at the first recording are shown in Table 6, and for the

TABLE 7

Second recording of postural angles

N = 12		Angles Measured					
	Subject	NSL/VER	NSL/OPT	NSL/CVT	OPT/HOR	CVT/HOR	OPT/CVT
AG	1	100.0	87.5	94.0	102.5	96.0	6.5
SL	2	93.5	101.0	106.5	82.5	77.0	5.5
AL	3	87.5	89.5	92.0	88.0	85.5	2.5
AS	4	92.5	89.0	93.0	93.5	89.5	4.0
CD	5	98.0	91.0	94.0	97.0	94.0	3.0
KD	6	89.0	98.0	102.5	81.0	76.5	5.0
SD	7	89.0	84.0	90.0	95.0	89.0	6.0
NS	8	90.0	87.0	97.0	93.0	83.0	10.0
NG	9	94.0	80.0	81.5	104.0	102.5	1.5
DH	10	92.5	111.0	111.0	71.5	71.5	0.0
MD	11	93.0	99.0	100.0	84.0	83.0	1.0
WK	12	89.0	86.0	90.0	93.0	89.0	4.0
Mean		92.33	91.92	95.96	90.42	86.38	4.10
S.D.		3.79	8.70	8.03	9.41	8.87	2.77

TABLE 7

Second recording of postural angles

N = 12		Angles Measured					
	Subject	NSL/VER	NSL/OPT	NSL/CVT	OPT/HOR	CVT/HOR	OPT/CVT
AG	1	100.0	87.5	94.0	102.5	96.0	6.5
SL	2	93.5	101.0	106.5	82.5	77.0	5.5
AL	3	87.5	89.5	92.0	88.0	85.5	2.5
AS	4	92.5	89.0	93.0	93.5	89.5	4.0
CD	5	98.0	91.0	94.0	97.0	94.0	3.0
KD	6	89.0	98.0	102.5	81.0	76.5	5.0
SD	7	89.0	84.0	90.0	95.0	89.0	6.0
NS	8	90.0	87.0	97.0	93.0	83.0	10.0
NG	9	94.0	80.0	81.5	104.0	102.5	1.5
DH	10	92.5	111.0	111.0	71.5	71.5	0.0
MD	11	93.0	99.0	100.0	84.0	83.0	1.0
WK	12	89.0	86.0	90.0	93.0	89.0	4.0
Mean		92.33	91.92	95.96	90.42	86.38	4.10
S.D.		3.79	8.70	8.03	9.41	8.87	2.77

TABLE 8

Difference between first and second recordings of postural angles

Subject		NSL/VER	NSL/OPT	NSL/CVT	OPT/HOR	CVT/HOR	OPT/CVT
AG	1	-9.0	-1.5	-2.0	-7.5	-7.0	-0.5
SL	2	-0.5	-5.5	-5.0	5.0	4.5	0.5
AL	3	0.5	-5.5	-6.0	6.0	6.5	-0.5
AS	4	-1.0	-1.0	1.0	0.0	-2.0	2.0
CD	5	3.0	6.0	6.5	-3.0	-3.5	0.0
KD	6	5.5	-5.0	-1.5	10.5	7.0	3.0
SD	7	3.5	3.0	2.5	0.5	1.0	-0.5
NS	8	-3.0	2.5	2.0	-5.5	-5.0	-0.5
NG	9	8.5	2.5	3.0	6.0	5.5	0.5
DH	10	4.5	-2.5	0.0	7.0	4.5	2.5
MD	11	-3.0	-2.0	-3.0	-1.0	0.0	-1.0
WK	12	-1.0	-1.0	-2.0	0.0	1.0	-1.0

TABLE 9

Means and standard deviations and standard errors and 't' values for the differences between the first and second sets of recordings of postural angles

	Mean	S.D.	S.E.	Min.	Max.	S(i)	't'	
NSL/VER	0.67	4.67	1.35	-9.00	8.50	3.20 (2.25)*	0.494	n.s.
NSL/OPT	-0.83	3.68	1.006	-5.50	6.00	2.56 (3.39)*	0.784	n.s.
NSL/CVT	-0.38	3.58	1.03	-6.00	6.50	2.44 (3.37)*	0.363	n.s.
OPT/HOR	1.50	5.44	1.57	-7.50	10.50	3.84 (3.07)*	0.955	n.s.
CVT/HOR	1.04	4.68	1.35	-7.00	7.00	3.25 (3.09)*	0.772	n.s.
OPT/CVT	0.38	1.38	0.40	-1.00	3.00	0.97 (0.90)*	0.938	n.s.

* Method error s(i) of a previous study [Siersbaek-Nielsen & Solow (1982)] for comparison.

second recording in Table 7. The differences between the first and second recordings were statistically analysed. The means, standard deviations, standard errors, ranges, method errors and values for 't' for these differences are shown in Table 9.

The error of the method for the position of the head to the true vertical NSL/VER was 3.2°, for the cranio-cervical angulation NSL/OPT 2.6° and for the cervical vertebral tangent NSL/CVT 2.4°.

The cervical inclination OPT/HOR method error was 3.8°, the variable CVT/HOR 3.3° and the variable OPT/CVT 0.97°.

No systematic differences significant at the 5% level were seen between the two sets of recordings.

This study serves to demonstrate that a reproducible head posture position exists that can be recorded with a method error of only a few degrees. This compares well with a previous study by Siersbaek-Nielsen & Solow (1982) who found the following method errors:- NSL/VER = 2.25°, NSL/OPT = 3.39°, NSL/CVT = 3.37°, OPT/HOR = 3.07°, CVT/HOR = 3.09° and OPT/CVT = 0.90° (Table 8).

b) **Digitiser Variables**

Equipment error determination

This method error component consisted of machine variables.

1. The error due to reproducibility of the X and Y co-ordinates for a single point.

2. The linearity distortion over the active field of the digitiser.

1. Error of the method for reproducibility of a single point by the digitiser

This error test was carried out to check the reproducibility of the cursor located co-ordinates. A sheet of paper with eight fine pin holes numbered 1 - 8 was located in the active area of the digitiser in the position a cephalometric radiograph would be located. The paper was secured to the illuminated screen with adhesive tape.

The Graf-bar sonic digitiser was switched on for one hour prior to the study measurements being made. This allowed temperature stabilisation of the unit to take place.

The cursor was placed over each point in turn and the X and Y co-ordinates written to a computer disk file with the help of a programme written for the study. After one hour the procedure was repeated and a method error for the duplicate determination was calculated using the Hald statistic (Hald 1960).

TABLE 10

Method error test for single point reproducibility by the digitiser

X Co-ordinates

Point	1st Value	2nd Value		Difference
1	11.994	11.940		0.054
2	4.484	4.501		-0.017
3	4.301	4.298		0.003
4	3.792	3.854		-0.062
5	4.716	4.806		-0.090
6	6.264	6.280		-0.016
7	12.234	12.245		-0.011
8	13.566	13.586		-0.020
			Mean	-0.007
			SD	0.050
			SE	0.018
			S(i)	0.044 cm
			t	-0.393 (n.s.)

TABLE 11

Method error test for single point reproducibility by the digitiser

Y Co-ordinates

Point	1st Value	2nd Value		Difference
1	0.888	0.862		0.026
2	0.941	0.972		-0.031
3	7.242	7.214		0.028
4	9.714	9.709		0.005
5	10.790	10.799		-0.009
6	10.203	10.233		-0.020
7	7.888	7.879		0.009
8	3.652	3.655		-0.003
			Mean	0.001
			SD	0.021
			SE	0.007
			S(i)	0.014 cm
			t	0.0852 (n.s.)

Results

The first and second recordings of the X co-ordinates are shown in Table 10. The values for the Y co-ordinates are shown in Table 11.

The means, standard deviations, standard errors, method errors and values for 't' were calculated for the differences between the first and second values for the X and Y co-ordinates.

The error of the method for digitiser reproducibility of a single point was 0.44 mm for the X axis and 0.14 mm for the Y axis. No significant differences at the 5% level were seen between the two sets of recordings.

2. The linearity distortion over the active field of the digitiser

The linearity distortion due to the machine error is more accurately assessed if the sheet of paper with the eight pin holes is shifted between each set of measurements throughout the active area of the digitiser. Recordings of the point co-ordinates for the eight points allowed for calculation of line lengths between:-

Point 1-2
Point 2-3
Point 3-4
Point 4-5
Point 5-6
Point 6-7
Point 7-8

Twenty recordings of each point were made to enable the calculation of seven line lengths for each position of the point sets (Table 12).

For each pair of recordings for each line length, the difference was calculated. The actual length of each linear dimension (cm) was measured with a steel rule with vernier gauge to two decimal places.

The linearity distortion occurring for each position of the paper in the active field reflects the true machine error because the resulting value is made up of twice the point placement error, i.e. the line is drawn from two points; plus any error occurring due to linear distortion.

The method error test was repeated ten times overall using paired sets of values to highlight any significant distortions over the active field of the digitiser.

Results

The results for the 20 sets of recordings for the seven line lengths are shown in Table 12, together with the means, standard deviations and standard errors. The actual line length for each value measured with a steel rule to the nearest 0.01 cm is shown.

In no case was the location error more than 0.5 mm between the actual length and the mean digitised dimension.

TABLE 12

Line lengths between points in the active field of the digitiser (cm)

	Point 1-2	Point 2-3	Point 3-4	Point 4-5	Point 5-6	Point 6-7	Point 7-8
1	7.520	6.276	2.478	1.443	1.627	6.419	4.434
2	7.570	6.264	2.448	1.381	1.635	6.456	4.464
3	7.532	6.343	2.448	1.495	1.625	6.401	4.441
4	7.570	6.353	2.545	1.396	1.630	6.439	4.427
5	7.571	6.269	2.575	1.432	1.660	6.533	4.462
6	7.551	6.261	2.533	1.381	1.648	6.379	4.484
7	7.490	6.297	2.514	1.406	1.692	6.325	4.446
8	7.510	6.274	2.479	1.415	1.662	6.394	4.351
9	7.520	6.303	2.493	1.371	1.648	6.358	4.389
10	7.462	6.271	2.507	1.482	1.651	6.403	4.419
11	7.550	6.276	2.516	1.463	1.614	6.399	4.459
12	7.520	6.226	2.519	1.479	1.593	6.477	4.438
13	7.516	6.221	2.488	1.373	1.610	6.397	4.474
14	7.500	6.343	2.475	1.401	1.683	6.403	4.419
15	7.488	6.280	2.513	1.372	1.586	6.453	4.398
16	7.475	6.348	2.464	1.473	1.616	6.398	4.391
17	7.495	6.251	2.476	1.475	1.647	6.452	4.403
18	7.481	6.298	2.487	1.392	1.705	6.352	4.393
19	7.498	6.283	2.458	1.434	1.585	6.410	4.390
20	7.471	6.357	2.497	1.365	1.644	6.416	4.428
Mean	7.515	6.290	2.497	1.426	1.638	6.413	4.425
S.D.	0.034	0.041	0.031	0.044	0.033	0.047	0.034
S.E.	0.008	0.009	0.007	0.008	0.007	0.010	0.008
S(i)	0.023	0.056	0.029	0.051	0.027	0.051	0.029
Actual Length	7.55 cm	6.29 cm	2.49 cm	1.44 cm	1.64 cm	6.45 cm	4.42 cm

Location accuracy to within 0.056 cm

c) **Nasal Resistance Variables**

Error of the rhinomanometric method for assessment of nasal resistance

To assess the error of the method for rhinomanometric recordings, 12 subjects from the total sample had duplicate measurements made at the same recording session. An interval occurred between the first and second sets of recordings during which time standardised cephalometric radiographic films were taken of the subject for use in the study.

The sample consisted of 5 males and 7 females (N = 12) in the age range 10 to 21 years.

Measurements were made for total or bilateral nasal resistance using recordings obtained by the posterior method, and for the right and left unilateral nasal resistance using values obtained by the anterior method. The rhinomanometer (NR3) calculated a value for nasal resistance after four respiratory cycles and the duplicate determination was carried out with an interval between the two sets of measurements.

Systematic differences between the two sets of values were assessed by 't' tests for paired sampled. The error variance was assessed by the Hald statistic (Hald 1960).

TABLE 13

Duplicate determination of rhinomanometric recordings for posterior values of nasal resistance during inspiration (Pascals/cc/sec x 10^3)

	Subject	First recorded value	Second recorded value	Difference
JK	1	340.4	408.9	-68.5
MD	2	322.0	338.8	-16.8
LS	3	135.8	133.5	2.3
RM	4	192.7	181.2	11.5
JW	5	206.6	195.7	10.9
RN	6	296.8	282.7	14.1
GP	7	205.0	181.6	23.4
AW	8	185.3	141.1	43.9
EG	9	144.7	144.1	0.6
LT	10	150.8	146.8	4.1
LM	11	343.4	322.6	20.8
DL	12	166.1	151.5	14.6

N = 12 Each measurement was calculated as the mean of four recordings.

TABLE 14

Duplicate determination of rhinomanometric recordings for posterior values of nasal resistance during expiration (Pascals/cc/sec x 10^3)

Subject		First recorded value	Second recorded value	Difference
JK	1	275.3	312.8	-37.5
MD	2	289.2	279.0	10.2
LS	3	128.1	125.9	2.3
RM	4	160.6	163.8	-3.2
JW	5	170.6	185.3	-14.7
RN	6	255.4	234.4	21.0
GP	7	163.7	161.2	2.5
AW	8	165.9	124.5	41.4
EG	9	145.0	127.0	18.0
LT	10	148.6	157.3	-8.7
LM	11	325.4	313.4	12.0
DL	12	160.5	163.3	-2.0

N = 12 Each measurement was calculated as the mean of four recordings.

TABLE 15

Duplicate determination of rhinomanometric recordings for anterior values of left side nasal resistance during inspiration (Pascals/cc/sec x 10^3)

Subject		First recorded value	Second recorded value	Difference
JK	1	767.5	712.7	54.8
MD	2	547.4	408.0	139.4
LS	3	305.8	292.4	13.4
RM	4	320.6	313.6	7.0
JW	5	396.3	398.7	-2.4
RN	6	441.2	468.6	-27.4
GP	7	423.0	406.1	16.9
AW	8	301.6	309.8	-8.2
EG	9	346.2	336.4	9.8
LT	10	538.8	491.3	47.5
LM	11	557.4	554.6	2.8
DL	12	321.2	341.7	-20.5

N = 12 Each measurement was calculated as the mean of four recordings.

TABLE 16

Duplicate determination of rhinomanometric recordings for anterior values of left side nasal resistance during expiration (Pascals/cc/sec x 10^3)

	Subject	First recorded value	Second recorded value	Difference
JK	1	722.8	699.5	23.3
MD	2	609.1	609.2	-0.1
LS	3	293.0	266.5	26.5
RM	4	323.3	318.4	4.9
JW	5	428.7	454.6	-25.9
RN	6	490.5	419.3	71.2
GP	7	368.3	370.8	-2.5
AW	8	309.5	308.0	1.5
EG	9	325.8	325.5	0.3
LT	10	580.2	516.3	63.9
LM	11	528.5	548.9	-19.7
DL	12	275.7	327.4	-22.6

N = 12 Each measurement was calculated as the mean of four recordings.

TABLE 17

Duplicate determination of rhinomanometric recordings for anterior values of right side nasal resistance during inspiration (Pascals/cc/sec x 10^3)

Subject		First recorded value	Second recorded value	Difference
JK	1	622.6	665.4	-42.8
MD	2	512.3	338.0	174.3
LS	3	337.9	325.2	12.7
RM	4	298.5	275.1	23.4
JW	5	471.5	457.0	14.5
RN	6	462.5	433.7	28.8
GP	7	362.1	379.7	-17.6
AW	8	327.5	350.2	-22.7
EG	9	322.3	352.2	-29.9
LT	10	444.2	441.2	3.0
LM	11	721.2	665.2	56.0
DL	12	379.1	328.5	50.6

N = 12 Each measurement was calculated as the mean of four recordings.

TABLE 18

Duplicate determination of rhinomanometric recordings for anterior values of right side nasal resistance during expiration (Pascals/cc/sec x 10^3)

Subject		First recorded value	Second recorded value	Difference
JK	1	503.6	523.7	-20.6
MD	2	494.9	378.6	116.3
LS	3	326.7	342.7	-16.0
RM	4	258.4	249.2	9.2
JW	5	497.6	463.6	34.0
RN	6	403.6	393.0	10.6
GP	7	332.4	352.6	-20.2
AW	8	317.5	337.5	-20.0
EG	9	297.9	348.4	-50.5
LT	10	430.8	400.7	30.1
LM	11	618.2	544.4	73.8
DL	12	319.1	298.0	21.1

N = 12 Each measurement was calculated as the mean of four recordings.

TABLE 19

Duplicate determination of nasal respiratory resistance (NRR) for posterior and anterior measurements (Pascals/cc/sec x 10^3)

Method	Pressure threshold (Pascals)	Sample size N		1 recording			2 recording			Difference				
				Mean	S.D.	S.E.	Mean	S.D.	S.E.	Mean	S.D.	S.E.	S(i)	t
Posterior	150	12	Insp.	224.1	79.0	22.8	219.0	94.1	27.2	5.1	27.4	7.9	18.9	0.642 n.s.
			Exp.	199.0	67.2	19.4	195.7	71.0	20.5	3.8	19.7	5.7	13.6	0.675 n.s.
Ant. Left	150	12	Insp.	438.9	141.1	40.7	419.5	122.4	35.3	19.4	44.8	12.9	33.3	1.503 n.s.
			Exp.	437.95	146.5	42.3	430.4	136.9	39.5	7.6	35.0	10.11	24.3	0.750 n.s.
Ant. Right	150	12	Insp.	438.5	130.0	37.53	417.6	127.4	36.8	20.9	57.3	16.6	41.5	1.260 n.s.
			Exp.	400.0	109.3	31.6	386.0	87.2	25.2	14.0	46.1	13.3	32.7	1.051 n.s.

Results

Rhinomanometric measurements for posterior values for inspiration and expiration for first and second recordings are shown in Tables 13 and 14. The values for left side nasal resistance during inspiration and expiration are shown in Tables 15 and 16 and for right side nasal resistance during inspiration and expiration in Tables 17 and 18.

The summary table (Table 19) shows the analysis of the data for the first and second recordings and the differences between the two sets of measurements.

The statistical analysis (Table 19) showed that the recordings could be repeated with no systematic differences. The method errors ranged from 13.6 to 41.5 Pascals/cc/sec x 10^3. This constituted 1.4% to 5.2% of the total variances in the control sample.

d) **Cephalometric Variables**

In order to assess the total error of the method for the point placement by the operator, and point location by the digitiser, 12 subjects from the cleft lip (CL) sample had cephalometric points defined and recorded on acetate tracing paper and then digitised. This was repeated one day later to enable comparison of the measurements obtained for the same linear and angular variables. Three subjects from the total cleft lip (CL) sample (N=15) were excluded due to absent soft tissue nasal tip which was missing on the radiograph.

A statistical analysis of 64 linear and angular variables was carried out using the facilities of the Northern European Computing Centre (NECC), Lyngby, Copenhagen, Denmark. A facility for data transmission and reception was developed as part of the project between Edinburgh and Copenhagen. This enabled the recorded cephalometric data to be transferred by the author, from the Edinburgh University mainframe computer via the European Research Network (EARNET) to Denmark, for analysis.

The computer programme for the project, to store the digitised co-ordinate data was designed to prompt on the VDU screen for each point in numeric sequence and bleep as each point co-ordinate was recorded. When digitising was complete, an image of the points, connected by lines, of the skull structures was displayed on the screen. This system design was included to ensure that the correct point sequence was followed and that all points were digitised.

The data was then used to create a plot of the image shown on the VDU screen (Fig. 12). This illustration of the skull and soft tissue profile structures was drawn by a plotter on acetate tracing paper. The trace was used as a further error check by superimposition on the cephalometric radiograph and also on the original acetate trace to confirm that a correct recording had been made.

As a further check of point placement accuracy three parameters which are useful in appraising the shape of distributions were employed. These are measures of skewness and kurtosis $\sqrt{b1}$, b2 and a (Solow 1966). The mean of the skewness $\sqrt{b1}$ (distribution symmetry) in samples from a normal distribution is zero (Pearson 1931).

The measure of kurtosis b2 (degree of peak of a distribution) has a mean of 3 in samples from a normal distribution; lower values indicate platykurtosis (flat hump distribution), and higher values leptokurtosis (narrow sharp peaks) (Rao 1952). Geary's (1935, 1936) measure of kurtosis, a, for small samples was used to further evaluate the distribution, the mean value being 0.8 for samples drawn from normal distribution.

Scrutiny of the results of skewness and kurtosis values (Tables 20, 21 and 22) enabled digitising errors to be detected due to gross distribution errors being revealed in the values $\sqrt{b1}$, b2 and a.

Results

Linear and angular dimensions for the 64 variables used for the cephalometric analysis of the 12 subjects from the cleft lip (CL) category are shown in Table 20. The results of the second recordings of the same dimensions are shown in Table 21 and the analysis of the differences between the first and second recordings are tabulated in Table 22.

The parameters shown are the mean ($\bar{x}$), standard error of the mean ($s(\bar{x})$), standard deviation (s), variance (s^2), skewness ($\sqrt{b1}$), kurtosis (b2), Geary's test (a), and, for the analysis of the differences between the two sets of recordings, the method error (s(i)), value of t and % experimental error (Trenouth et al 1985). Digitiser error was found in two subjects due to incorrect point sequence during the recording and this was corrected.

No systematic differences significant at the 5% level were demonstrated between the two sets of recordings. The 57 cephalometric points used in the study could be reproduced with a small method error ranging between 2.4 mm for ils-NL and 0.4 mm for ii-gn. The error expressed as a function of the error variance $(s(i))^2$, and the total variance s^2 in percentage was found by multiplying the error equation x 10. The values had already been enhanced x 10 (from centimetres to millimetres) for the computer analysis, the smallest percentage error being 4.5% and the largest 7.1%.

Reproducible cephalometric values could therefore be obtained for subjects in the study without systematic differences and with a small method error and small experimental percentage error.

TABLE 20

Cleft lip (three subjects excluded)

CL1

Variable (N = 12)	NR	Range Min.	Max.	$\bar{x}$ Mean	Standard error of mean $s(\bar{x})$	Standard Deviation s	Variance s^2	Skewness $\sqrt{b1}$	Kurtosis b2	Geary's test a
n-s	1	65.8	74.2	69.34	0.759	2.63	6.91	0.207	1.98	0.8886
n-sp	2	42.8	58.3	49.40	1.473	5.10	26.04	0.170	1.76	0.9148
n-gn	3	94.3	132.6	112.83	3.141	10.88	118.42	0.200	2.61	0.7647
s-ba	4	39.9	51.1	45.12	1.064	3.68	13.58	-0.010	1.95	0.8309
s-ar	5	25.6	39.3	33.85	1.342	4.65	21.60	-0.459	1.90	0.8877
s-pm	6	33.3	51.1	44.35	1.269	4.40	19.33	-1.034	4.61	0.7188
s-tg	7	61.7	93.3	75.00	2.696	9.34	87.25	0.230	2.40	0.8638
sp-gn	8	52.2	80.8	65.86	2.532	8.77	76.91	0.237	2.03	0.8544
ar-tgo	9	34.6	61.3	46.66	1.920	6.68	44.66	0.620	3.10	0.7625
sp-pm	10	45.2	63.5	43.59	1.407	4.87	23.74	0.476	2.97	0.7565
ss-pm	11	44.2	55.1	49.38	0.908	3.15	9.90	-0.127	2.59	0.8026
pgn-cd	12	100.7	126.3	112.66	2.411	8.35	69.76	0.180	1.75	0.8829
pg-tgo	13	60.2	78.0	69.68	1.545	4.35	28.64	-0.368	2.14	0.8314

linear dimensions mm

angular dimensions degrees

CL1

Table 20 (contd.)

Variable (N = 12)	NR	Range Min.	Max.	$\bar{x}$ Mean	Standard error of mean $s(\bar{x})$	Standard Deviation s	Variance s^2	Skewness $\sqrt{b1}$	Kurtosis b2	Geary's Test a
sp-is	14	15.9	35.7	27.26	1.406	4.87	23.72	-0.727	4.02	0.6801
ii-gn	15	33.1	48.1	39.83	1.165	4.03	16.28	0.352	2.78	0.8031
n-s-ba	16	128.7	140.0	133.88	1.100	3.81	14.53	-0.202	1.81	0.8665
n-s-ar	17	119.1	132.0	126.55	1.216	4.21	17.74	-0.202	1.86	0.8954
pm-s-ba	18	53.4	72.9	62.79	1.463	5.07	25.69	0.213	2.97	0.7827
s-n-sp	19	81.9	95.4	87.34	1.021	3.54	12.50	0.785	3.52	0.7253
s-n-ss	20	77.7	86.1	82.12	0.936	3.24	10.52	-0.049	1.42	0.9241
s-n-sm	21	72.3	81.8	76.45	0.946	3.28	10.73	0.486	1.82	0.8958
s-n-pg	22	74.1	82.8	77.90	0.884	3.06	9.38	0.372	1.82	0.8649
ss-n-sm	23	0.4	11.8	5.67	0.789	2.73	7.48	0.509	4.12	0.6719
ss-n-pg	24	-2.3	11.0	4.22	0.974	3.37	11.39	0.222	3.22	0.7761
NSL/NL	25	2.7	13.8	7.88	0.915	3.17	10.04	0.164	2.25	0.8681
NSL/ML	26	23.7	41.5	33.19	1.678	5.81	33.78	-0.134	1.87	0.8526
NL/ML	27	13.5	36.8	25.31	2.109	7.31	53.38	-0.155	2.06	0.8379
NSL/MBL	28	50.4	61.9	55.82	1.218	4.22	17.81	-0.035	1.55	0.8956
ML/RL	29	124.3	142.3	131.18	1.470	5.09	25.93	0.492	3.07	0.7576
IL_s/NL	30	71.5	110.7	95.28	3.123	10.82	117.07	-0.571	3.15	0.7801
ILi/ML	31	70.5	99.6	86.56	2.371	8.21	67.46	-0.385	2.64	0.7481

CL1

Table 20 (contd.)

Variable (N = 12)	NR	Range Min.	Range Max.	$\bar{x}$ Mean	Standard error of mean $s(\bar{x})$	Standard Deviation s	Variance s^2	Skewness $\sqrt{b1}$	Kurtosis b2	Geary's Test a
αj	32	-6.9	9.4	3.16	1.207	4.18	17.47	-0.751	4.17	0.6924
αb	33	-8.7	6.3	-0.29	1.282	4.44	19.72	-0.535	2.47	0.8129
NSL/VER	34	89.9	105.4	05.10	1.623	5.62	31.61	1.007	2.36	0.8308
NL/VER	35	76.1	100.7	87.22	2.073	7.18	51.55	0.547	2.58	0.8018
NSL/OPT	36	82.1	114.1	96.53	2.253	7.81	60.93	0.511	3.81	0.7679
NSL/CVT	37	93.1	115.4	101.01	1.807	6.26	39.20	0.781	3.34	0.7724
NL/OPT	38	71.9	109.4	88.65	2.835	9.82	96.42	0.481	3.17	0.7577
NL/CVT	39	80.2	110.7	93.12	2.447	8.48	71.87	0.527	2.88	0.7635
CPT/HOR	40	78.4	99.2	88.57	1.941	6.72	45.20	0.209	1.94	0.8564
CVT/HOR	41	74.7	90.7	84.09	1.510	5.23	27.38	-0.401	1.93	0.8941
FH/VER	42	80.5	93.4	86.22	1.141	3.95	15.62	0.096	2.12	0.8243
FH/OPT	43	72.9	102.1	87.65	2.100	7.27	52.91	0.086	3.56	0.6774
FH/CVT	44	83.8	103.3	92.12	1.688	5.85	34.18	0.743	2.45	0.8016
$pm\text{-}ad_1$	45	11.2	26.4	21.39	1.536	5.32	28.31	-1.013	2.37	0.8342
$pm\text{-}ad_2$	46	6.8	22.9	17.55	1.618	5.60	31.41	-0.727	2.23	0.8403
$pm\text{-}ad_3$	47	12.5	24.8	20.59	1.081	3.74	14.02	-1.114	3.21	0.7719
$tu\text{-}ad_3$	48	2.9	11.7	8.73	0.680	2.36	5.55	-1.278	4.18	0.7665
$n_s\text{-}sn$	49	42.7	62.0	51.29	1.919	6.65	44.19	0.288	1.83	0.8295

Table 20 (contd.)

CL1

Variable (N = 12)	NR	Range Min.	Max.	$\bar{x}$ Mean	Standard error of mean $s(\bar{x})$	Standard Deviation s	Variance s^2	Skewness $\sqrt{b1}$	Kurtosis b2	Geary's Test a
n_s-prn	50	33.5	56.3	42.81	1.965	6.81	46.34	0.467	2.32	0.8434
1nt to n-ss	51	6.1	9.3	7.60	0.309	1.07	1.14	0.384	1.94	0.8737
s-n_s-unt	52	106.3	119.7	113.27	1.177	4.08	16.63	-0.259	2.20	0.8084
sto to nl	53	22.0	34.0	26.29	1.077	3.73	13.91	0.739	2.60	0.8121
s-n_s-ss	54	84.4	96.3	88.97	1.003	3.48	12.08	0.644	2.58	0.8505
sn to 1nt-1_s	55	4.2	11.3	7.80	0.524	1.81	3.29	-0.091	3.01	0.7925
ls to NCL	56	0.7	12.9	5.35	1.225	4.24	18.01	0.440	1.81	0.8814
sto to ML	57	32.3	55.0	40.62	1.666	5.77	33.30	1.111	4.45	0.6994
s-n_s-sm_s	58	74.5	86.1	81.07	1.152	3.99	15.94	-0.168	1.54	0.9388
sm_s to li-pg_s	59	3.7	10.8	6.29	0.542	1.88	3.53	0.990	3.78	0.7478
li to NCL	60	0.2	9.8	4.37	0.995	3.45	11.87	0.295	1.64	0.8622
ss_s-n_s-sm_s	61	2.5	11.1	7.90	0.762	2.64	6.96	-0.456	2.52	0.8068
sto to OL_s	62	0.2	8.8	2.73	0.726	2.51	6.32	1.218	3.85	0.7824
s-n_s-pg_s	63	77.3	91.6	84.00	1.195	4.14	17.12	0.151	2.21	0.8455
NFL/NCL	64	138.7	158.9	148.72	1.927	6.67	44.54	0.023	1.69	0.8833

TABLE 21

Cleft lip error (three subjects excluded) - second digitization of cleft lip

CL2

Variable (N = 12)	NR	Range Min.	Max.	$\bar{x}$ Mean	Standard error of mean $s(\bar{x})$	Standard Deviation s	Variance s^2	Skewness $\sqrt{b1}$	Kurtosis b2	Geary's test a
n-s	1	65.8	74.9	69.55	0.801	2.77	7.70	0.270	2.21	0.8557
n-sp	2	42.3	59.1	49.70	1.662	5.76	33.14	0.145	1.64	0.9134
n-gn	3	93.4	131.5	113.26	3.123	10.82	117.06	-0.011	2.65	0.7422
s-ba	4	40.9	51.1	45.32	0.894	3.10	9.59	0.355	2.29	0.7854
s-ar	5	26.5	39.8	34.08	1.304	4.52	20.42	-0.360	1.86	0.8958
s-pm	6	38.4	49.9	44.53	1.000	3.46	12.00	0.072	2.21	0.8251
s-tg	7	61.2	93.3	75.31	2.705	9.37	87.82	0.194	2.33	0.8685
sp-gn	8	52.1	78.4	65.90	2.409	8.34	69.64	0.059	1.96	0.8553
ar-tgo	9	35.9	60.6	46.55	1.945	6.74	45.38	0.457	2.91	0.7610
sp-pm	10	47.3	63.2	53.54	1.293	4.48	10.06	0.710	2.97	0.7706
ss-pm	11	43.6	56.8	49.23	1.007	3.49	12.16	0.463	3.20	0.7721
pgn-cd	12	100.5	124.4	113.02	2.402	8.32	69.26	0.013	1.57	0.9197
pg-tgo	13	57.8	78.0	69.68	1.797	6.25	38.74	-0.604	2.32	0.8221

linear dimensions mm

angular dimensions degrees

CL2

Table 21 (contd.)

Variable (N = 12)	NR	Range Min.	Range Max.	$\bar{x}$ Mean	Standard error of mean $s(\bar{x})$	Standard Deviation s	Variance s^2	Skewness $\sqrt{b1}$	Kurtosis b2	Geary's Test a
sp-is	14	15.6	35.8	27.13	1.394	4.83	23.33	-0.739	4.40	0.6650
ii-gn	15	32.7	47.5	39.78	1.148	3.98	15.82	0.120	2.61	0.8242
n-s-ba	16	128.2	138.8	133.66	1.198	4.15	17.22	-0.292	1.46	0.9023
n-s-ar	17	117.9	131.8	126.41	1.331	4.61	21.27	-0.468	1.95	0.8789
pm-s-ba	18	51.3	71.6	61.94	1.383	4.29	22.96	-0.249	4.29	0.7011
s-n-sp	19	81.7	94.4	86.70	1.010	3.50	12.25	0.878	3.24	0.7940
s-n-ss	20	77.2	87.4	81.41	1.004	3.48	12.11	0.394	1.92	0.8609
s-n-sm	21	72.3	82.3	76.05	1.007	3.49	12.18	0.606	1.88	0.9063
s-n-pg	22	74.0	83.4	77.61	0.943	3.27	10.67	0.445	1.78	0.9037
ss-n-sm	23	0.5	9.2	5.37	0.657	2.28	5.18	-0.218	3.28	0.7604
ss-n-pg	24	-2.3	8.5	3.80	0.881	3.05	9.32	-0.163	2.56	0.8057
NSL/NL	25	2.1	12.9	7.76	0.959	3.32	11.03	-0.113	1.93	0.8660
NSL/ML	26	24.8	43.7	33.57	1.746	6.05	36.58	0.209	1.79	0.8886
NL/ML	27	14.0	38.9	25.81	2.160	7.48	55.97	-0.007	1.79	0.8886
NSL/MBL	28	50.3	62.6	56.41	1.218	4.22	17.81	-0.090	1.64	0.8791
ML/RL	29	123.5	146.7	130.79	1.768	6.12	37.49	1.335	4.86	0.6913
IL_s/NL	30	72.5	109.7	95.25	2.986	10.34	106.98	-0.721	3.18	0.7653
ILi/ML	31	72.3	102.7	87.50	2.601	9.01	81.16	-0.040	2.22	0.8123

CL2

Table 21 (contd.)

Variable (N = 12)	NR	Range Min.	Max.	$\bar{x}$ Mean	Standard error of mean $s(\bar{x})$	Standard Deviation s	Variance s^2	Skewness $\sqrt{b1}$	Kurtosis b2	Geary's Test a
oj	32	-7.8	8.6	2.59	1.191	4.12	17.01	-1.114	4.59	0.7259
ob	33	-8.6	3.5	-0.81	1.163	4.03	16.24	-0.545	2.09	0.8614
NSL/VER	34	88.9	106.1	95.16	1.713	5.93	35.22	0.921	2.30	0.9239
NL/VER	35	78.7	101.4	87.40	2.024	7.01	49.17	0.774	2.62	0.8025
NSL/OPT	36	81.4	110.8	96.53	2.076	7.19	51.73	-0.095	3.60	0.7472
NSL/CVT	37	93.4	114.4	100.99	1.742	6.04	36.43	0.740	3.12	0.7766
NL/OPT	38	71.6	106.0	88.77	2.662	9.22	85.04	0.105	2.85	0.7659
NL/CVT	39	83.6	109.7	93.23	2.277	7.89	62.19	0.860	2.88	0.7541
OPT/HOR	40	78.5	100.6	88.63	1.887	6.54	42.72	0.383	2.22	0.8636
CVT/HOR	41	73.8	90.4	84.17	1.434	4.97	24.67	-0.755	2.75	0.8150
FH/VER	42	80.9	94.7	85.85	1.186	4.11	16.88	0.667	2.77	0.8369
FH/OPT	43	71.5	199.4	87.21	2.089	7.24	52.38	-0.409	3.28	0.7242
FH/CVT	44	83.6	103.0	91.68	1.724	5.97	35.65	0.798	2.40	0.8037
$pm\text{-}ad_1$	45	14.0	27.2	21.91	1.343	4.65	21.65	-0.726	1.99	0.8785
$pm\text{-}ad_2$	46	7.1	23.2	17.52	1.435	4.97	24.70	-0.513	2.52	0.8579
$pm\text{-}ad_3$	47	15.9	24.8	21.06	0.827	2.86	8.20	-0.261	1.98	0.8779
$tu\text{-}ad_3$	48	1.9	10.8	8.47	0.712	2.47	6.08	-1.559	5.15	0.6945
$n_s\text{-}sn$	49	42.0	62.7	52.13	1.824	6.32	39.94	0.010	2.11	0.8138

CL2

Table 21 (contd.)

Variable (N = 12)	NR	Range Min.	Max.	$\bar{x}$ Mean	Standard error of mean $s(\bar{x})$	Standard Deviation s	Variance s^2	Skewness $\sqrt{b1}$	Kurtosis b2	Geary's Test a
n_s-prn	50	33.4	56.3	43.15	1.845	6.39	40.87	0.3421	2.81	0.7839
lnt to n-ss	51	6.0	9.6	7.72	0.312	1.08	1.17	0.221	2.04	0.8333
s-n_s-unt	52	103.2	118.6	112.75	1.475	5.11	26.10	-0.463	1.96	0.8734
sto to NL	53	22.2	34.3	26.56	1.068	3.70	13.69	0.859	2.79	0.7750
s-n_s-ss_s	54	83.8	94.2	88.29	1.113	3.86	14.87	0.379	1.64	0.8925
sn to lnt-l_s	55	4.3	9.7	7.71	0.410	1.42	2.02	-0.902	3.91	0.7507
ls to NCL	56	0.1	12.5	5.31	1.213	4.20	17.65	0.331	7.79	0.8672
sto to ML	57	31.6	53.7	40.89	1.630	5.65	31.87	0.539	3.59	0.7409
s-n_s-sm_s	58	75.4	86.6	80.85	1.162	4.03	16.20	0.046	1.48	0.9091
sm_s to li-pg_s	59	3.7	10.8	6.30	0.521	1.80	3.25	1.089	4.54	0.7015
li to NCL	60	0.1	9.8	4.37	0.989	3.43	11.74	0.248	1.56	0.8882
ss_s-n_s-sm_s	61	2.2	10.3	7.45	0.640	2.22	4.92	-0.840	3.74	0.7707
sto to OL_s	62	0.1	11.5	3.32	0.877	3.04	9.23	1.672	5.40	0.7090
s-n_s-pg_s	63	77.3	90.3	83.66	1.167	4.04	16.34	0.199	2.00	0.8706
NFL/NCL	64	138.6	159.2	148.60	1.912	6.62	43.88	0.049	1.96	0.8545

TABLE 22

Distribution of the differences between the duplicate measurements

CL Differences

Variable (N = 12)	NR	Range Min.	Max.	$\bar{x}$ Mean	Standard error of mean $s(\bar{x})$	Standard deviation s	Variance s^2	Skewness $\sqrt{b1}$	Kurtosis b2	Geary's test a	Method error s(i)	Value of t	% error
n-s	1	-1.4	1.2	0.22	0.216	0.75	0.56	-0.718	2.93	0.8307	0.528	0.999	5.0
n-sp	2	-0.8	2.3	0.30	0.268	0.93	0.86	0.795	2.79	0.8212	0.664	1.134	5.1
n-gn	3	-1.1	2.1	0.43	0.270	0.94	0.88	-0.070	2.35	0.8264	0.703	1.586	5.6
s-ba	4	-0.8	1.8	0.20	0.242	0.84	0.70	0.569	2.10	0.8822	0.583	0.809	4.8
s-ar	5	-0.7	1.3	0.23	0.173	0.60	0.36	-0.199	2.25	0.7852	0.437	1.313	5.3
s-pn	6	-1.5	5.0	0.19	0.492	1.70	2.90	1.997	6.69	0.6540	1.161	0.378	4.6
s-tg	7	-0.6	1.8	0.31	0.249	0.86	0.74	0.416	1.67	0.9167	0.624	1.250	5.3
sp-gn	8	-2.4	1.5	0.05	0.300	1.04	1.08	-0.788	3.79	0.7312	0.705	0.163	4.6
ar-tgo	9	-1.1	1.0	-0.09	0.182	0.63	0.40	0.047	2.14	0.8483	0.432	0.492	4.7
sp-pm	10	-3.4	3.0	-0.04	0.454	1.57	2.47	-0.023	3.66	0.7184	1.065	0.096	4.6
ss-pm	11	-5.2	1.8	-0.15	0.507	1.76	3.08	-2.020	6.82	0.6502	1.193	0.295	4.6
pgn-cd	12	-1.9	2.7	0.36	0.347	1.20	1.45	0.110	2.84	0.7918	0.853	1.034	5.0
pg-tgo	13	-2.3	1.8	0.01	0.357	1.24	1.53	-0.542	2.66	0.7162	0.837	0.016	4.6
sp-is	14	-1.5	1.1	-0.14	0.207	0.71	0.52	-0.238	2.68	0.7781	0.496	0.652	4.7
ii-gn	15	-1.0	1.1	-0.05	0.167	0.58	0.34	0.202	2.50	0.8339	0.394	0.311	4.5

$$\% \text{ error} = \frac{[s(i)]^2}{s2} \times 10$$

CL Differences

Table 22 (contd.)

Variable (N = 12)	NR	Range Min.	Max.	$\bar{x}$ Mean	Standard error of mean $s(\bar{x})$	Standard deviation s	Variance s^2	Skewness $\sqrt{b1}$	Kurtosis b2	Geary's test a	Method error s(i)	Value of t	% error
n-s-ba	16	-2.1	2.3	-0.22	0.412	1.43	2.04	0.629	2.20	0.7963	0.979	0.526	4.7
n-s-ar	17	-2.2	2.3	-0.13	0.433	1.50	2.25	0.444	1.81	0.8657	1.010	0.307	4.5
pm-s-ba	18	-4.1	2.8	-0.85	0.513	1.78	3.16	0.228	3.11	0.7890	1.347	1.661	5.7
s-n-sp	19	-3.0	1.7	-0.64	0.359	1.24	1.54	-0.049	2.86	0.7599	0.955	1.780	5.9
s-n-ss	20	-3.0	1.3	-0.70	0.341	1.18	1.40	-0.053	2.71	0.7340	0.943	1.063	6.4
s-n-sm	21	-1.4	0.7	-0.40	0.194	0.67	0.45	0.071	1.98	0.8178	0.536	2.065	6.4
s-n-pg	22	-1.3	0.6	-0.29	0.161	0.56	0.31	0.098	1.48	0.8081	0.428	1.795	5.9
ss-n-sm	23	-2.6	0.8	-0.30	0.263	0.91	0.83	-1.352	4.40	0.7536	0.654	1.154	5.2
ss-n-pg	24	-2.5	0.7	-0.42	0.256	0.89	0.79	-1.108	3.82	0.7317	0.669	1.624	5.7
NSL/NL	25	-5.4	3.9	-0.13	0.642	2.22	4.95	-0.632	4.48	0.6579	1.508	0.198	4.6
NSL/ML	26	-0.8	2.2	0.38	0.273	0.95	0.90	0.460	2.05	0.8494	0.694	1.378	5.4
NL/ML	27	-2.7	4.7	0.50	0.612	2.12	4.49	0.269	2.67	0.8169	1.478	0.824	4.9
NSL/MBL	28	-1.2	2.3	0.59	0.269	0.93	0.87	0.118	3.28	0.6827	0.755	2.186	6.6
ML/RL	29	-3.0	4.4	-0.39	0.522	1.81	3.27	1.330	5.37	0.6728	1.256	0.756	4.8
IL_s/NL	30	-8.6	6.1	-0.03	1.030	3.57	12.72	-0.817	4.28	0.7032	2.415	0.027	4.6
ILi/ML	31	-2.6	3.2	0.95	0.510	1.77	3.12	-0.676	2.65	0.7926	1.371	1.854	6.0
oj	32	-5.3	2.1	-0.57	0.503	1.74	3.03	-1.456	5.82	0.6393	1.246	1.134	5.1
ob	33	-9.1	1.8	-0.52	0.820	2.84	8.06	-2.501	8.23	0.6058	1.957	0.632	4.8
NSL/VER	34	-1.0	0.8	0.06	0.182	0.63	0.40	-0.129	1.75	0.8998	0.429	0.325	4.6

CL Differences

Table 22 (contd.)

Variable (N = 12)	NR	Range Min.	Max.	$\bar{x}$ Mean	Standard error of mean $s(\bar{x})$	Standard deviation s	Variance s^2	Skewness $\sqrt{b1}$	Kurtosis b2	Geary's test a	Method error s(i)	Value of t	% error
NL/VER	35	-3.2	4.4	0.19	0.569	1.97	3.88	0.203	3.42	0.7158	1.340	0.328	4.6
NSL/OPT	36	-3.3	1.9	-0.01	0.440	1.52	2.32	-0.769	2.85	0.8356	1.032	0.017	4.5
NSL/CVT	37	-2.8	1.4	-0.02	0.311	1.08	1.16	-1.235	4.57	0.6883	0.730	0.061	4.6
NL/OPT	38	-5.4	6.6	0.12	0.873	3.02	9.15	0.234	3.44	0.7179	2.049	0.138	4.6
NL/CVT	39	-3.1	5.4	0.11	0.656	2.27	5.16	0.690	3.68	0.7441	1.539	0.166	4.6
OPT/HOR	40	-2.2	4.1	0.07	0.543	1.88	3.53	0.744	2.63	0.8301	1.274	0.122	4.6
CVT/HOR	41	-1.1	2.7	0.08	0.334	1.16	1.34	1.156	3.33	0.8075	0.785	0.234	4.6
FH/VER	42	-1.9	1.3	-0.37	0.264	0.91	0.83	0.222	2.40	0.8321	0.671	1.408	5.4
FH/OPT	43	-4.2	1.7	-0.44	0.517	1.79	3.21	-0.659	2.55	0.8314	1.251	0.847	4.9
FH/CVT	44	-2.8	1.1	-0.45	0.277	0.96	0.92	1.111	4.54	0.7236	0.724	1.621	5.7
$pm-ad_1$	45	-2.7	5.2	0.52	0.515	1.78	3.19	1.074	5.65	0.5777	1.263	1.005	5.0
$pm-ad_2$	46	-2.1	5.4	-0.02	0.572	1.98	3.92	1.722	5.83	0.6763	1.341	0.043	4.6
$pm-ad_3$	47	-1.9	4.9	0.47	0.521	1.81	3.26	1.092	4.28	0.7462	1.267	0.906	4.9
$tu-ad_3$	48	-1.4	1.0	-0.27	0.230	0.80	0.64	0.107	1.78	0.8986	0.572	1.166	5.1
n_s-sn	49	-1.4	3.8	0.84	0.454	1.57	2.47	0.538	2.45	0.7990	1.220	1.852	6.0
n_s-prn	50	-3.1	2.2	0.34	0.454	1.57	2.47	-0.580	2.92	0.7962	1.091	0.744	4.8
lnt to n-ss	51	-1.5	1.2	0.12	0.223	0.77	0.60	-0.402	2.64	0.7991	0.530	0.546	4.7

CL Differences

Table 22 (contd.)

Variable (N = 12)	NR	Range Min.	Range Max.	$\bar{x}$ Mean	Standard error of mean $s(\bar{x})$	Standard deviation s	Variance s^2	Skewness $\sqrt{b1}$	Kurtosis b2	Geary's test a	Method error s(i)	Value of t	% error
$s\text{-}n_s\text{-}unt$	52	-4.3	3.3	-0.52	0.722	2.50	6.26	-0.148	2.04	0.8137	1.734	0.725	4.8
sto to NL	53	-1.0	1.4	0.28	0.176	0.61	0.37	-0.304	3.42	0.7585	0.456	1.568	4.6
$s\text{-}n_s\text{-}ss_s$	54	-3.3	1.3	-0.68	0.429	1.48	2.20	-0.304	1.87	0.8510	1.113	1.580	5.6
sn to $lnt\text{-}l_s$	55	-1.6	1.3	-0.10	0.226	0.78	0.61	-0.236	2.52	0.8057	0.535	0.422	4.7
ls to NCL	56	-1.8	0.8	-0.04	0.205	0.71	0.50	-1.210	4.35	0.7439	0.481	0.192	4.6
sto to ML	57	-1.4	1.9	0.27	0.287	0.99	0.99	0.233	2.09	0.8384	0.699	0.929	4.9
$s\text{-}n_s\text{-}sm$	58	-2.0	1.3	-0.22	0.287	0.99	0.99	-0.213	1.97	0.8767	0.690	0.768	4.8
sm_s to $li\text{-}pg_s$	59	-0.8	7.2	0.00	0.238	0.82	0.68	1.662	5.47	0.7209	0.558	0.012	4.5
li to NCL	60	-1.1	1.0	0.01	0.196	0.68	0.46	0.026	1.98	0.8362	0.460	0.028	4.6
$ss_s\text{-}n_s\text{-}sm_s$	61	-1.7	1.0	-0.46	0.253	0.88	0.77	0.233	1.77	0.8721	0.676	1.805	5.9
sto to OL_s	62	-0.3	2.6	0.60	0.242	0.84	0.70	1.175	3.89	0.7624	0.706	2.463	7.1
$s\text{-}n_s\text{-}pg_s$	63	-2.5	1.7	-0.36	0.342	1.19	1.41	-0.032	2.36	0.8422	0.842	1.052	5.1
NFL/NCL	64	-2.1	1.7	-0.12	0.315	1.09	1.19	0.019	2.43	0.8240	0.744	0.356	4.7

CHAPTER 6

RESULTS

A Rhinomanometric Results

Nasal airway resistance was recorded unilaterally for each nasal half, as well as bilaterally for the total naso-pharyngeal airway in all subjects. This enabled a general comparison of upper airway resistance to be made, as well as an analysis of the resistance of each nasal half. Inter-sample comparisons were made by unpaired t tests with equal or unequal variances. Differences in variance were assessed by Fishers F test for variance ratio.

Total upper airway resistance

A survey of the total upper airway resistance in all the groups is given in Table 23. In the controls, mean nasal resistance values of 323 Pascals/cc/sec x 10^3 and 325 Pascals/cc/sec x 10^3 were found for inspiration and expiration respectively.

In the cleft groups mean resistance values ranged from 301 to 410 Pascals/cc/sec x 10^3. None of these values differed significantly from each other or from the controls, nor were there any consistent differences between the mean nasal resistance for inspiration and expiration.

TABLE 23

Total nasal respiratory resistance, posterior method
Comparison of mean values for inspiration and expiration. p values based upon student t tests between each cleft group and the control group
Pascals/cc/sec x 10^3 at 150 Pascals

		Inspiration			Expiration		
	n	$\bar{x}$	s.d.	p	$\bar{x}$	s.d.	p
Cleft lip	15	399.8	269.3	0.168	377.9	268.0	0.383
Cleft palate	19	380.9	197.5	0.192	410.0	264.6	0.140
Unilateral cleft lip & palate	27	311.0	91.6	0.692	301.0	97.4	0.507
Control	38	322.7	132.5		324.6	164.5	

$\bar{x}$ derived from inspirational and expirational component of 16 respiratory cycles

Unilateral nasal respiratory resistance

The unilateral analysis of nasal resistance in the control group showed mean values of about 560 Pascals/cc/sec x 10^3 in each side.

In the cleft lip group (CL) (Table 24), nasal resistance on the cleft side was 1044 and 900 Pascals/cc/sec x 10^3 for inspiration and expiration respectively, whereas the non-cleft side showed values of 599 and 593 Pascals/cc/sec x 10^3 respectively. The cleft side resistance was significantly higher than the non-cleft side ($p<0.01$) and the control ($p<0.01$).

In the unilateral cleft lip and palate group (UCLP) (Table 25), a similar pattern was found with a mean resistance of 1088 and 969 Pascals/cc/sec x 10^3 on the cleft side and 463 and 446 Pascals/cc/sec x 10^3 in the non-cleft side. The resistance in the cleft side was significantly higher than that in the controls ($p<0.01$ for inspiration, $p<0.05$ for expiration) and the resistance in the non-cleft side was significantly lower than in the controls ($p<0.01$ for inspiration, $p<0.05$ for expiration).

In the cleft palate group (CP) (Table 26), the resistances of the right and left nasal halves did not differ significantly, neither did the resistance values differ significantly for the right nasal compartment when compared to the controls. However mean values for nasal resistance for the left nasal half were

TABLE 24

Unilateral nasal respiratory resistance in cleft lip (CL), anterior method Comparison of mean values for inspiration and expiration. p values based upon student t tests between each cleft group and the control group Pascals/cc/sec x 10^3 at 150 Pascals

		Inspiration			Expiration		
	n	$\overline{x}$	s.d.	p	$\overline{x}$	s.d.	p
CL Cleft side (10L + 5R)	15	1043.6	688.7	0.010**	899.6	504.3	0.050*
CL Non-cleft side (5L + 10R)	15	599.4	373.9	0.356	592.9	452.7	0.350
Difference between cleft and non- cleft side		444.2***			306.7***		
Control (38 left)	38	552.6	193.8		560.0	204.1	
Control (38 right)	38	560.0	181.8		571.6	204.4	

*** : $p \leq 0.001$

** : $p \leq 0.01$

* : $p \leq 0.05$

TABLE 25

Unilateral nasal respiratory resistance in unilateral cleft lip and palate (UCLP), anterior method
Comparison of mean values for inspiration and expiration. p values based upon student t tests between each cleft group and the control group
Pascals/cc/sec x 10^3 at 150 Pascals

		Inspiration			Expiration		
	n	$\bar{x}$	s.d.	p	$\bar{x}$	s.d.	p
UCLP, Cleft side (18L + 9R)	27	1088.2	770.8	0.012**	968.7	675.7	0.050*
UCLP, Non cleft Side (9L + 18R)	27	463.2	130.3	0.006**	445.8	136.3	0.050*
Difference between cleft and non-cleft side		625.0***			522.9***		
Control (38 left)	38	552.6	193.8		560.0	204.1	
Control (38 right)	38	560.0	181.8		571.6	204.4	

*** : $p \leq 0.001$
** : $p \leq 0.01$
* : $p \leq 0.05$

TABLE 26

Unilateral nasal respiratory resistance in cleft palate, anterior method
Comparison of mean values for inspiration and expiration. p values based upon student t tests between each cleft group and the control group
Pascals/cc/sec x 10^3 at 150 Pascals

		Inspiration			Expiration		
	n	$\bar{x}$	s.d.	p	$\bar{x}$	s.d.	p
Cleft palate (19 left)	19	742.8	373.3	0.014*	815.6	623.9	0.025*
Cleft palate (19 right)	19	546.3	186.5	0.791	573.5	213.8	0.974
Difference between right and left side		196.5 n.s.			242.1 n.s.		
Control (38 left)	38	552.6	193.8		560.0	204.1	
Control (38 right)	38	560.0	181.8		571.6	204.4	

* : $p \leq 0.05$

somewhat higher and differed significantly from the controls ($p<0.05$).

Discussion of Rhinomanometric Results

Registration of the resistance of the nasal and naso-pharyngeal airway to airflow raises several problems of methodological as well as interpretative nature (Broms _et al_ 1982d). Among the methodological problems are the reliability of the equipment, the adaption of the face mask that carries the pneumotachograph, the condition of the nasal mucosa and, for the recording by the posterior method, whether the patient is able to open the valve formed by the soft palate and the dorsum of the tongue. Regarding the interpretation of the records there have been diverging opinions as to how to represent the recorded pressure flow data by a single resistance value (Broms _et al_ 1982b).

In the present investigation, the measuring equipment was calibrated dynamically before each recording session since pressure transducers may behave differently under static and dynamic conditions.

The selection of a mask for the pneumotachograph is dependent upon the type of recording to be made (Gurley & Vig 1982). When posterior recordings are required, the need for slight initial adjustments of the oral tubing makes a mask that only covers the nose preferable to one that covers the mouth and nose. A simple scuba diving mask with a plain acrylic window, and no other modification of the rubber face seal for nose clips or snorkel, was used. This was found to be efficient and easier to use than an anaesthetic nose mask lined individually with dental impression material (Solow & Greve 1980).

Since the study aimed to examine the differentiated pattern of airway resistance caused by the varying anatomical configuration of the nasal cavity, the possible effect of the varying condition of the nasal mucosa was reduced by administration of 0.1% xylometazoline hydrochloride (Broms et al 1981).

For recording of total nasal resistance by the posterior method, failure rates of 25-50% have been reported in the literature (Drettner 1960). The adoption of the modified oral tubing and a bio-feedback technique with on-line screen presentation of the pressure-flow curve as proposed by Solow & Greve (1980) resulted in a rejection rate of zero in the present study.

According to Bachmann & Bacher (1984) the pressure flow curve consists of an expiratory and inspiratory part, each of which can be described by a second degree polynomium. For practical clinical purposes, however, the committee report on standardization of rhinomanometry (Clement 1984) recommended the use of the resistance value calculated at a point on the curve corresponding to a pressure difference (threshold value) of 150 Pascals. The recommendation was followed throughout the present study. The analysis of the method error showed that with the above method, the measurement could be reproduced with an error variance of only 1.4 to 5.2% of the sample variance.

The analysis of the duplicate measurements showed a reproducibility without systematic error, and with a small method error. Larger method errors have been reported for this method of measurement (Solow & Greve 1980). The improvement in accuracy may be related to the different type of mask and the frequent and dynamic calibration used in the study.

Nasal respiratory resistance has been studied previously in subjects with clefting deformity of the lip and palate (Warren *et al* 1969). The findings demonstrated larger nasal resistances in cleft groups than controls. The further studies (Warren *et al* 1974) indicated that pharyngeal flap surgical procedures increase nasal airway resistance. Drettner (1960) using measurements of nasal resistance to compute airway dimension demonstrated that narrowing of the nasal airway occurred in 45% of a sample of patients with cleft deformity when compared to a control group. In both these studies the results were not analysed according to type of cleft, and unilateral nasal resistance was not measured.

The findings in the present study are at variance with those presented by Warren since in the present study no difference in total bilateral nasal resistance was observed between the cleft groups and controls. Several factors in the present study could account for this disagreement. One factor might be related to the use of a decongestant in the present study (Bende 1985); another, the use of a fixed threshold (150 Pascals).

The international recording method used in the present study only interprets a single point on the pressure-flow curve. The data thus are not representative of some flow and pressure conditions in more vigorous exercise and speech. With newer technology it may become possible to record linear and turbulent flow components representing the total respiratory cycle (Hasegawa & Kern 1978).

In the present investigation the cleft sample was categorized into subgroups according to Pruzansky (1953). <u>In cleft lip</u> (CL) the anomaly is confined to the primary palate. The contraction of the scar tissue associated with the repair of the lip causes narrowing and distortion of the nasal aperture. The liminal valve of the aperture is responsible for much of the nasal resistance to airflow in the child. This valve effect may be enhanced by the repair. On inspiration, furthermore, the deformed nostril, which may not be well supported by cartilage, can be drawn in, further increasing the nasal resistance. The results of the present study, showing that the cleft side has a significantly higher nasal resistance than the non-cleft side or the control, are therefore not surprising.

<u>In the unilateral cleft lip and palate category</u> (UCLP) both the primary and secondary palate are affected by the deformity, and the

integrity of the palate is breached. After repair the effect of the scar tissue contraction on the smaller segment is to draw it inwards, thus restricting the nasal compartment on the affected side. Added to this is the soft tissue contraction at the nasal aperture. Subjects with clefts of the lip (CL) show little overall effect on the craniofacial structures (Dahl 1970), but cleft lip and palate deformity has a more widespread effect and involves nasal septum which is almost always distorted towards the cleft side (Drettner 1960). In agreement with this, the results of the present study show that the cleft side has a significantly higher nasal resistance than the control group. The non-cleft side, on the other hand, has a significantly lower nasal resistance than the controls. The differences in resistance might in part be due to the deviation of the lower part of the nasal septum towards the cleft. However the turbinate erectile tissue on the non-cleft side might to some extent compensate for the abnormal anatomy of the area (Hasegawa & Kern 1977).

<u>The cleft palate category</u> (CP) shows interesting results in that the overall differences for the values for nasal resistance, although higher, differ significantly from the controls for the left side only. The cleft deformity invades the integrity of the soft and hard palate to a greater or lesser extent, but does not divide the total extent of the palate as in unilateral cleft lip

and palate (UCLP), and it does not involve the soft tissue nasal aperture. However the nasal septum may have a variable deviation to one side or the other, which in this sample may be predominantly to the left. This could account for the higher values recorded for this side.

In evaluation of these findings it should be noted that craniofacial development in cleft lip and palate children may depend on the varying type and extent of the surgical procedures used to correct the deformity and also on the personal skills of the individual surgeon. The subjects in the present sample had surgery performed by different surgeons at two hospitals in the Edinburgh area. It remains to be seen whether similar results are obtained from patients treated at other centres for correction of cleft deformity.

B **Cephalometric**

The results of the analysis of the standardised lateral cephalometric radiographs of the control group are shown in Table 27. The linear dimensions are expressed in millimetres and the angular measurements in whole degrees. The table displays the 64 linear and angular variables recorded for head posture, cranial base, maxilla, mandible, dento-alveolar and soft tissue morphology.

TABLE 27

Cephalometric statistical data for the control group

Variable (N = 38)	NR	Range Min.	Max.	$\bar{x}$ Mean	Standard error of mean $s(\bar{x})$	Standard Deviation s	Variance s^2	Skewness $\sqrt{b1}$	Kurtosis b2
n-s	1	63.4	80.4	71.35	0.636	3.92	15.38	0.072	2.74
n-sp	2	44.1	62.9	51.91	0.734	4.53	20.49	0.574	2.73
n-gn	3	99.3	146.0	117.25	1.639	10.11	102.13	0.924	4.12
s-ba	4	40.3	55.0	46.60	0.643	3.97	15.73	0.535	2.42
s-ar	5	27.8	43.4	34.98	0.743	4.58	20.95	0.346	2.02
s-pm	6	42.1	60.5	48.15	0.722	4.45	19.82	0.850	3.17
s-tgo	7	62.9	93.2	76.74	1.356	8.36	69.90	0.092	1.44
sp-gn	8	56.0	88.0	67.55	1.097	6.70	44.92	0.808	4.06
ar-tgo	9	32.5	61.5	46.11	1.134	6.99	48.85	0.096	2.77
sp-pm	10	43.1	64.6	54.01	0.844	5.20	27.04	-0.179	2.65
ss-pm	11	40.0	58.1	49.79	0.724	4.46	19.90	-0.200	2.65
pgn-cd	12	100.0	137.2	119.17	1.462	9.01	81.17	0.182	2.44
pt-tgo	13	63.9	87.5	76.18	1.011	6.23	38.83	0.120	2.29
sp-is	14	21.7	39.2	28.75	0.581	3.58	12.85	0.738	4.17

Table 27 (contd.)

Variable (N = 38)	NR	Range Min.	Range Max.	$\overline{x}$ Mean	Standard error of mean $s(\overline{x})$	Standard Deviation s	Variance s^2	Skewness $\sqrt{b1}$	Kurtosis b2
ii-gn	15	35.6	50.5	41.85	0.580	3.58	12.79	0.454	3.04
n-s-ba	16	119.9	143.7	130.68	0.931	5.74	32.94	0.189	2.86
n-s-ar	17	115.0	140.4	123.47	0.901	5.56	30.87	0.840	3.71
pm-s-ba	18	48.2	77.5	59.93	1.121	6.91	47.72	0.268	2.68
s-n-sp	19	77.2	98.9	87.86	0.802	4.95	24.46	0.289	2.91
s-n-ss	20	74.4	91.9	82.71	0.662	4.08	16.67	0.205	3.03
s-m-sm	21	70.3	86.7	78.87	0.656	4.05	16.37	-0.009	2.26
s-n-pg	22	70.3	87.3	80.01	0.688	4.24	17.96	-0.003	2.40
ss-n-sm	23	-10.3	10.0	3.84	0.574	3.54	12.51	-1.467	8.03
ss-n-pg	24	-12.5	10.5	2.70	0.668	4.12	16.98	-1.113	6.22
NSL/NL	25	-1.3	10.7	6.82	0.443	2.73	7.46	-0.791	3.63
NSL/ML	26	20.5	50.2	33.57	1.185	7.31	53.40	0.231	2.32
NL/ML	27	12.4	39.7	26.75	1.165	7.18	51.55	-0.229	2.22
NSL/MBL	28	48.6	66.8	56.13	0.849	5.23	27.37	0.532	2.30
ML/RL	29	114.5	147.9	129.24	1.111	6.85	46.89	-0.064	3.46
IL_s/NL	30	95.5	124.3	109.70	1.064	6.56	42.99	0.047	2.96
IL_i/ML	31	72.7	113.5	92.18	1.544	9.52	90.58	-1.173	2.73
oj	32	-6.6	11.4	4.60	0.524	3.23	10.44	-1.095	5.64

Table 27 (contd.)

Variable (N = 38)	NR	Range Min.	Max.	$\bar{x}$ Mean	Standard error of mean $s(\bar{x})$	Standard Deviation s	Variance s^2	Skewness $\sqrt{b1}$	Kurtosis b2
ob	33	-10.0	4.0	-2.76	0.421	2.59	6.72	0.201	4.32
NSL/VER	34	82.0	108.4	93.93	0.984	6.06	36.76	0.423	3.18
NL/VER	35	76.3	101.3	87.11	0.916	5.65	31.87	0.452	3.03
NSL/OPT	36	79.2	112.9	94.71	1.342	8.27	68.42	-0.025	2.25
NSL/CVT	37	85.4	122.5	99.34	1.258	7.75	60.09	0.535	3.43
NL/OPT	38	70.9	105.1	87.90	1.157	7.13	50.90	-0.148	3.18
NL/CVT	39	79.7	114.6	92.52	1.107	6.82	46.53	0.681	4.48
OPT/HOR	40	73.5	106.0	89.21	1.151	7.10	50.36	0.215	2.76
CVT/HOR	41	69.1	99.8	84.59	1.115	6.87	47.24	0.090	2.85
FH/VER	42	71.6	95.9	84.34	0.896	5.52	30.51	-0.180	2.93
FH/OPT	43	69.6	100.7	85.12	1.217	7.50	56.27	-0.158	2.21
FH/CVT	44	78.2	110.2	89.75	1.119	6.90	47.56	0.447	3.21
$pm\text{-}ad_1$	45	5.8	32.1	20.18	0.799	4.93	24.29	-0.173	4.33
$pm\text{-}ad_2$	46	6.1	29.1	16.33	0.668	4.12	16.96	0.289	4.56
$pm\text{-}ad_3$	47	13.2	32.5	20.78	0.584	3.60	12.95	0.803	4.89
$tu\text{-}ad_3$	48	3.7	13.1	8.50	0.325	2.00	4.02	0.183	3.15
$n_s\text{-}sn$	49	40.8	65.8	51.28	1.034	6.38	40.65	0.376	2.32
$n_s\text{-}prn$	50	32.8	57.0	43.72	0.961	5.77	33.27	0.340	10.87

Table 27 (contd.)

Variable (N = 38)	NR	Range Min.	Max.	$\bar{x}$ Mean	Standard error of mean $s(\bar{x})$	Standard Deviation s	Variance s^2	Skewness $\sqrt{b1}$	Kurtosis b2
lnt to n-ss	51	4.8	10.3	7.70	0.172	1.06	1.12	-0.444	3.62
$s-n_s-unt$	52	103.3	132.3	119.34	0.792	4.75	22.61	-0.549	7.90
sto to NL	53	17.0	35.2	25.44	0.612	3.52	12.36	0.067	3.69
$s-n_s-ss_s$	54	83.0	102.6	93.54	0.610	3.82	14.57	-0.031	3.68
sn to $lnt-l_s$	55	5.8	11.5	8.08	0.237	1.43	2.03	0.495	7.00
ls to NCL	56	0.5	10.9	3.94	0.480	2.88	8.29	0.912	9.44
sto to ML	57	37.8	56.7	45.52	0.781	4.49	20.14	0.576	6.91
$s-n_s-sm_s$	58	77.1	98.8	85.02	0.666	4.10	16.84	0.831	4.80
sm_s to $li-pg_s$	59	1.6	9.5	5.31	0.260	1.60	2.57	0.194	3.17
li to NCL	60	0.42	9.4	3.21	0.423	2.54	6.44	0.802	6.13
$ss_s-n_s-sm_s$	61	-5.7	15.1	8.35	0.552	3.40	11.57	-1.677	8.90
sto to OL_s	62	0.5	13.3	4.82	0.453	2.60	6.77	0.936	12.65
$s-n_s-pg_s$ PGS	63	77.3	100.1	86.27	0.687	4.23	17.92	0.761	4.60
NFL/NCL	64	133.1	169.4	145.89	1.014	6.09	37.05	1.293	12.69

TABLE 28

Cephalometric statistical data for cleft lip category

Variable (N = 15)	NR	Range Min.	Max.	$\overline{x}$ Mean	Standard error of mean $s(\overline{x})$	Standard Deviation s	Variance s^2	Skewness $\sqrt{b1}$	Kurtosis b2
n-s	1	65.8	76.1	70.34	0.827	3.20	10.27	0.169	1.98
n-sp	2	42.8	60.7	50.13	1.397	5.41	29.26	0.363	2.22
n-gn	3	94.3	132.6	114.37	2.769	10.73	115.04	-0.026	2.35
s-ba	4	39.9	54.2	46.24	1.103	4.27	18.25	0.126	2.21
s-ar	5	25.6	42.0	34.65	1.224	4.74	22.45	-0.436	2.20
s-pm	6	33.3	55.0	45.58	1.322	5.12	26.20	-0.326	3/78
s-tgo	7	61.7	93.3	76.57	2.540	9.84	96.74	0.119	2.03
sp-gn	8	52.2	80.8	66.51	2.151	8.33	69.41	0.159	2.10
ar-tgo	9	36.5	61.3	47.20	1.647	6.38	40.67	0.405	2.83
sp-pm	10	45.2	63.5	54.04	1.143	4.43	19.61	0.209	3.23
ss-pm	11	44.2	55.1	49.62	0.737	2.85	8.14	-0.367	3.07
pgn-cd	12	100.7	127.2	114.76	2.287	8.86	78.46	-0.065	1.68
pg-tgo	13	60.2	78.9	71.00	1.446	5.60	31.37	-0.480	2.29
sp-is	14	15.9	35.7	27.97	1.241	4.80	23.08	-0.706	4.14

CL

Table 28 (contd.)

Variable (N = 15)	NR	Range Min.	Max.	$\bar{x}$ Mean	Standard error of mean $s(\bar{x})$	Standard Deviation s	Variance s^2	Skewness $\sqrt{b1}$	Kurtosis b2
ii-gn	15	33.1	48.1	40.30	1.012	3.92	15.37	0.208	2.67
n-s-ba	16	128.3	140.0	133.30	0.998	3.87	14.95	-0.022	1.64
n-s-ar	17	118.1	132.0	125.81	1.141	4.42	19.54	-0.174	1.96
pm-s-ba	18	52.9	72.9	61.86	1.377	5.33	28.45	0.140	2.77
s-n-sp	19	81.9	95.4	87.06	0.873	3.38	11.44	0.733	3.77
s-n-ss	20	77.7	86.1	81.75	0.791	3.06	9.39	0.186	1.53
s-n-sm	21	72.3	81.8	76.60	0.772	2.99	8.93	0.390	1.97
s-n-pg	22	74.1	82.8	78.09	0.717	2.78	7.72	0.215	2.01
ss-n-sm	23	0.4	11.8	5.15	0.691	2.68	7.16	0.771	4.18
ss-n-pg	24	-2.3	11.0	3.66	0.832	3.22	10.37	0.574	3.39
NSL/NL	25	1.2	13.8	7.25	0.856	3.32	10.99	0.080	2.58
NSL/ML	26	23.7	41.5	32.64	1.400	5.42	29.39	0.070	2.01
NL/ML	27	13.5	36.8	25.39	1.743	6.75	45.59	-0.204	2.23
NSL/MBL	28	50.4	61.9	55.88	0.986	3.82	14.59	-0.080	1.80
ML/RL	29	118.9	142.3	139.22	1.502	5.82	38.83	0.021	2.85
IL_s/NL	30	71.5	110.7	96.99	2.643	10.23	104.75	-0.916	3.61
IL_i/ML	31	70.5	99.6	87.18	2.005	7.76	60.28	-0.511	2.79
oj	32	-6.9	9.4	3.98	1.065	4.13	17.02	-0.949	4.27

CL

Table 28 (contd.)

Variable (N = 15)	NR	Range Min.	Max.	$\bar{x}$ Mean	Standard error of mean $s(\bar{x})$	Standard Deviation s	Variance s^2	Skewness $\sqrt{b1}$	Kurtosis b2
ob	33	-8.7	6.3	-1.01	1.089	4.22	17.78	-0.103	2.23
NSL/VER	34	89.9	105.4	94.89	1.328	5.14	26.44	1.119	2.82
NL/VER	35	76.1	100.7	87.64	1.704	6.60	43.55	0.395	2.70
NSL/OPT	36	82.1	114.1	96.80	2.137	8.28	68.52	0.234	2.90
NSL/CVT	37	88.0	115.4	101.13	1.856	7.19	51.66	0.131	2.60
NL/OPT	38	71.9	109.4	89.55	2.604	10.09	101.73	0.233	2.42
NL/CVT	39	80.2	110.7	93.88	2.352	9.11	83.01	0.215	2.09
OPT/HOR	40	78.4	199.2	88.10	1.786	6.92	47.87	0.244	1.78
CVT/HOR	41	74.7	93.0	83.77	1.507	5.84	34.06	-0.042	1.68
FH/VER	42	10.5	93.4	86.18	1.025	3.97	15.75	-0.019	2.00
FH/OPT	43	72.9	102.1	98.08	2.157	8.35	69.76	-0.073	2.61
FH/CVT	44	77.6	103.9	92.41	1.921	7.44	55.36	-0.032	2.38
pm-ad_1	45	11.2	26.4	20.89	1.248	4.83	23.36	-0.766	2.31
pm-ad_2	46	6.8	22.9	17.19	1.314	5.09	25.92	-0.580	2.36
pm-ad_3	47	12.5	25.2	21.07	0.914	3.54	12.53	-1.279	3.92
tu-ad_3	48	2.9	11.7	8.90	0.560	2.17	4.70	-1.433	4.99
n_s-sn	49	42.7	64.6	52.23	1.760	6.82	46.48	0.320	2.07
n_s-prn	50	33.5	56.3	43.25	1.701	6.36	40.49	0.324	6.16

CL

Table 28 (contd.)

Variable (N = 15)	NR	Range Min.	Max.	$\bar{x}$ Mean	Standard error of mean $s(\bar{x})$	Standard Deviation s	Variance s^2	Skewness $\sqrt{b1}$	Kurtosis b2
lnt to n-ss	51	6.1	9.3	7.45	0.262	1.01	1.03	0.632	2.31
$s\text{-}n_s\text{-}unt$	52	106.3	119.7	113.61	1.047	3.92	15.36	-0.463	10.62
sto to NL	53	22.0	33.9	26.21	0.994	3.58	12.84	0.941	12.72
$s\text{-}n_s\text{-}ss_s$	54	84.4	96.3	89.37	0.904	3.50	12.25	0.405	2.09
sn to $lnt\text{-}l_s$	55	4.2	12.9	8.22	0.576	2.16	4.64	0.470	2.72
ls to NCL	56	0.4	21.6	5.79	1.553	6.02	36.19	1.283	4.10
sto to ML	57	32.3	55.0	40.90	1.558	5.62	31.54	1.100	4.35
$s\text{-}n_s\text{-}sm_s$	58	74.5	86.1	81.29	0.950	3.68	13.55	-0.278	1.78
sm_s to $li\text{-}pg_s$	59	3.7	10.8	6.47	0.464	1.80	3.23	0.746	3.34
li to NCL	60	0.2	9.8	3.79	0.935	3.49	12.23	0.570	3.28
$ss_s\text{-}n_s\text{-}sm_s$	61	2.5	11.1	8.08	0.644	1.49	6.22	-0.556	2.68
sto to OL_s	62	0.2	8.8	2.70	0.668	2.41	5.81	1.474	11.64
$s\text{-}n_s\text{-}pg_s$	63	77.3	91.6	84.02	0.983	3.81	14.50	0.146	2.41
NFL/NCL	64	138.7	158.9	148.46	1.707	6.39	40.78	0.097	7.50

TABLE 29

Cephalometric statistical data for cleft palate category

Variable (N = 19)	NR	Range Min.	Max.	$\bar{x}$ Mean	Standard error of mean $s(\bar{x})$	Standard Deviation s	Variance s^2	Skewness $\sqrt{b1}$	Kurtosis b2
n-s	1	61.3	81.0	70.40	1.031	4.50	20.21	0.078	3.54
n-sp	2	40.2	61.9	51.32	1.353	5.90	34.76	0.049	2.15
n-gn	3	99.0	143.8	115.90	3.198	13.94	194.30	0.854	2.53
s-ba	4	37.5	55.2	46.18	1.187	5.17	26.75	0.272	2.49
a-ar	5	22.5	46.5	33.92	1.254	5.47	29.87	0.458	3.69
s-pm	6	34.2	58.2	44.09	1.447	6.31	39.80	0.527	2.71
s-tgo	7	62.5	91.9	73.15	1.869	8.15	66.38	0.862	2.62
sp-gn	8	54.5	85.5	66.27	2.126	9.27	85.92	1.954	2.95
ar-tgo	9	36.5	55.7	42.90	1.230	5.36	28.73	0.634	2.79
sp-pm	10	43.9	57.3	50.43	0.962	4.19	17.58	0.205	1.94
ss-pm	11	40.0	53.9	45.46	0.942	4.10	16.84	0.412	2.17
pgn-cd	12	92.2	134.9	112.26	2.846	12.40	153.86	0.365	2.23
pg-tgo	13	52.4	85.0	69.68	2.104	9.17	84.08	-0.272	2.34
sp-is	14	23.8	36.2	28.30	0.802	3.50	12.23	0.806	2.70

CP

Table 29 (contd.)

Variable (N = 19)	NR	Range Min.	Max.	$\bar{x}$ Mean	Standard error of mean $s(\bar{x})$	Standard Deviation s	Variance s^2	Skewness $\sqrt{b1}$	Kurtosis b2
ii-gn	15	31.9	51.6	40.85	1.205	5.25	27.58	0.728	2.90
n-s-ba	16	115.5	137.8	127.90	1.498	6.53	42.61	-0.321	2.30
n-s-ar	17	109.1	132.3	121.30	1.406	6.13	37.56	-0.056	2.48
pm-s-ba	18	46.7	74.5	57.86	1.633	7.12	50.69	0.376	2.71
s-n-sp	19	71.8	93.3	83.08	1.332	5.81	33.71	-0.003	2.59
s-n-ss	20	67.6	86.4	77.23	1.194	5.20	27.07	0.092	2.60
s-n-sm	21	67.1	83.2	75.64	0.957	4.17	17.40	-0.163	2.56
s-n-pg	22	69.3	83.8	76.83	0.933	4.07	16.53	-0.095	2.22
ss-n-sm	23	-7.5	9.3	1.58	0.988	4.31	18.54	-0.524	2.82
ss-n-pg	24	-8.7	7.7	0.40	1.010	4.40	19.30	-0.384	2.47
NSL/NL	25	0.2	20.6	10.66	1.407	6.13	37.64	-0.016	1.86
NSL/ML	26	29.4	44.6	37.42	1.154	5.03	25.30	-0.148	1.81
NL/ML	27	14.5	44.0	26.77	1.478	6.44	41.49	0.407	4.24
NSL/MBL	28	51.9	66.5	58.40	0.958	4.17	17.43	0.101	2.09
ML/RL	29	120.3	142.9	133.17	1.486	6.48	41.94	-0.363	2.10
IL_s/NL	30	96.4	121.4	106.72	1.537	6.70	41.94	-0.363	2.33
IL_i/ML	31	72.8	95.6	82.91	1.407	6.03	37.62	0.188	2.32
oj	32	-4.1	10.2	3.31	1.045	4.56	20.76	-0.473	2/10

CP

Table 29 (contd.)

Variable (N = 19)	NR	Range Min.	Max.	$\bar{x}$ Mean	Standard error of mean $s(\bar{x})$	Standard Deviation s	Variance s^2	Skewness $\sqrt{b1}$	Kurtosis b2
ob	33	-7.9	1.2	-2.87	0.561	2.45	5.99	-0.228	2.48
NSL/VER	34	88.8	104.1	94.66	0.885	3.86	14.87	0.944	3.56
NL/VER	35	73.0	95.9	83.98	1.520	6.63	43.91	-0.004	2.21
NSL/OPT	36	75.2	112.8	94.53	2.245	9.79	95.77	-0.337	2.71
NSL/CVT	37	75.1	114.2	99.83	2.052	8.94	79.98	-0.937	4.28
NL/OPT	38	58.3	100.9	83.87	2.621	11.42	130.48	-0.418	2.30
NL/CVT	39	72.6	104.4	89.17	2.387	10.41	108.27	-0.260	1.73
OPT/HOR	40	70.4	110.7	90.11	2.547	11.10	123.22	0.340	2.23
CVT/HOR	41	68.9	106.2	84.81	2.324	10.13	102.59	0.611	2.49
FH/VER	42	74.5	93.9	85.32	1.097	4.78	22.85	-0.201	2.93
FH/OPT	43	68.7	104.8	85.21	2.248	9.80	96.05	-0.101	2.28
FH/CVT	44	68.6	106.3	90.51	1.068	9.01	81.24	-0.736	3.17
$pm\text{-}ad_1$	45	13.5	24.7	17.60	0.753	3.28	10.77	0.654	2.26
$pm\text{-}ad_2$	46	9.8	20.9	14.05	0.766	3.34	11.14	0.541	2.27
$pm\text{-}ad_3$	47	10.9	25.0	18.28	0.904	3.94	15.53	-0.079	1.96
$tu\text{-}ad_3$	48	4.9	11.8	8.22	0.467	2.04	4.14	0.026	2.04
$n_s\text{-}sn$	49	38.4	65.8	52.54	1.839	8.02	64.28	-0.042	2.10
$n_s\text{-}prn$	50	28.1	56.6	44.60	1.756	7.66	58.61	-0.313	2.48

CP

Table 29 (contd.)

Variable (N = 19)	NR	Range Min.	Max.	$\bar{x}$ Mean	Standard error of mean $s(\bar{x})$	Standard Deviation s	Variance s^2	Skewness $\sqrt{b1}$	Kurtosis b2
lnt to n-ss	51	5.4	12.0	8.11	0.349	1.52	2.32	0.640	3.62
s-n_s-unt	52	102.4	122.7	113.39	1.198	5.22	27.27	-0.078	2.62
sto to NL	53	18.6	34.0	25.71	1.215	4.71	22.16	0.590	3.78
s-n_s-ss_s	54	80.2	96.2	88.91	1.039	4.53	20.52	-0.071	2.02
sn $_t$o lnt-l_s	55	5.4	9.8	7.67	0.252	1.10	1.21	-0.203	2.76
ls to NCL	56	0.3	13.15	3.90	0.755	3.29	10.84	1.305	4.41
sto to ML	57	33.4	57.3	44.00	1.807	7.00	48.97	0.608	5.76
s-n_s-sm_s	58	73.7	89.2	81.38	0.934	4.07	16.56	0.127	2.66
sm_s to li-pg_s	59	2.5	7.0	4.66	0.288	1.26	1.58	0.048	2.09
li to NCL	60	0.1	10.3	2.65	0.561	2.44	5.97	1.625	5.91
ss_s-n_s-sm_s	61	0.9	13.5	7.53	0.827	3.60	12.99	-0.163	2.17
sto to ol_s	62	0.9	7.6	4.27	0.614	2.38	5.65	0.241	7.88
s-n_s-pg_s	63	76.0	90.5	82.44	0.921	4.01	16.10	0.415	2.66
NFL/NCL	64	136.2	154.7	145.42	1.062	4.63	21.43	0.154	2.85

TABLE 30

Cephalometric statistical data for the unilateral cleft lip and palate category

Variable (N = 27)	NR	Range Min.	Max.	$\overline{x}$ Mean	Standard error of mean $s(\bar{x})$	Standard Deviation s	Variance s^2	Skewness $\sqrt{b1}$	Kurtosis b2
n-s	1	65.9	79.3	72.38	0.695	3.61	13.05	0.074	2.13
n-sp	2	45.6	65.8	53.80	0.957	4.97	24.72	0.241	2.70
n-gn	3	107.5	143.0	124.59	1.865	9.69	93.90	0.088	2/09
s-ba	4	41.6	56.4	49.19	0.631	3.28	10.75	-0.058	2.85
s-ar	5	27.9	44.1	36.78	0.666	3.46	11.98	0.052	3.55
s-pm	6	38.3	57.8	45.83	0.924	4.80	23.05	0.480	2.77
s-tgo	7	63.0	97.4	80.39	1.646	8.55	73.18	-0.059	2.38
sp-gn	8	59.6	82.6	72.00	1.243	6.46	41.70	-0.226	2.00
ar-tgo	9	37.0	62.7	48.20	1.296	6.74	45.38	0.228	2.35
sp-pm	10	40.8	59.7	53.48	0.927	4.82	23.20	-0.919	3.35
ss-pm	11	35.6	55.2	47.48	0.844	4.38	19.21	-1.083	4.28
pgn-cd	12	107.7	138.7	122.59	1.751	9.10	82.82	0.132	1.85
pg-tgo	13	67.0	84.8	75.33	1.056	5.49	30.12	0.238	1.70
sp-is	14	24.0	35.1	29.84	0.565	2.94	8.63	0.223	2.14

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Table 30 (contd.)

Variable (N = 27)	NR	Range Min.	Max.	$\bar{x}$ Mean	Standard error of mean $s(\bar{x})$	Standard Deviation s	Variance s^2	Skewness $\sqrt{b1}$	Kurtosis b2
ii-gn	15	36.3	50.8	44.37	0.736	3.83	14.63	-0.285	2.32
n-s-ba	16	120.1	147.9	130.70	1.271	6.60	43.60	0.855	3.21
n-s-ar	17	114.7	138.6	125.40	1.198	6.22	38.74	0.260	2.16
pm-s-ba	18	47.6	64.0	55.43	0.938	4.87	23.74	0.197	1.88
s-n-sp	19	68.7	89.8	81.39	1.070	5.56	30.91	-0.479	2.59
s-n-ss	20	65.6	81.7	75.14	0.904	4.70	22.08	-0.354	2.11
s-n-sm	21	65.6	82.5	75.50	0.754	3.92	15.34	-0.464	3.24
s-n-pg	22	68.0	84.0	77.15	0.781	4.06	16.47	-0.557	3.05
ss-n-sm	23	-10.5	5.2	-0.36	0.830	4.31	18.61	-0.852	2.90
ss-n-pg	24	-13.8	4.7	-2.02	0.901	4.68	21.94	-0.730	2.94
NSL/NL	25	-1.8	19.9	9.48	0.989	5.14	26.42	-0.191	2.59
NSL/ML	26	25.2	49.5	36.49	1.196	6.21	38.62	0.356	2.38
NL/ML	27	14.0	37.6	27.02	1.243	6.46	41.72	-0.416	2.71
NSL/MBL	28	53.4	70.9	59.09	0.904	4.70	22.06	1.067	3.55
ML/RL	29	120.1	148.7	130.46	1.381	7.18	51.50	0.470	2.76
IL_s/NL	30	10.3	121.4	103.30	1.466	7.62	58.02	0.263	2.71
IL_i/ML	31	68.2	99.4	84.21	1.568	8.15	66.38	-0.105	2.36
oj	32	-13.5	7.3	-0.64	0.913	4.74	22.51	-0.645	3.04

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Table 30 (contd.)

Variable (N = 27)	NR	Range Min.	Max.	$\bar{x}$ Mean	Standard error of mean $s(\bar{x})$	Standard Deviation s	Variance s^2	Skewness $\sqrt{b1}$	Kurtosis b2
ob	33	-8.1	3.6	-2.53	0.577	3.00	8.99	-0.086	2.27
NSL/VER	34	86.9	105.3	94.90	0.966	5.02	25.20	0.564	2.56
NL/VER	35	69.9	94.0	85.42	1.163	6.04	36.50	-0.414	2.78
NS/OPT	36	86.0	119.3	100.07	1.582	8.22	67.60	0.254	2.71
NSL/CVT	37	86.7	123.2	103.52	1.662	8.63	74.55	0.142	2.91
NL/OPT	38	70.4	107.8	90.59	1.799	9.35	87.38	-0.128	2.62
NL/CVT	39	70.2	109.8	94.05	1.922	9.99	99.74	-0.360	2.68
OPT/HOR	40	75.8	101.5	84.83	1.305	6.78	45.99	0.629	2.76
CVT/HOR	41	71.4	101.6	81.38	1.427	7.41	55.01	0.856	3.28
FH/VER	42	75.7	93.3	85.21	0.895	4.65	21.63	0.020	2.30
FH/OPT	43	72.3	104.6	90.38	1.572	8.17	66.69	-0.463	2.45
FH/CVT	44	72.2	108.5	93.83	1.652	8.58	73.66	-0.691	2.91
$pm-ad_1$	45	3.9	24.7	17.96	0.833	4.33	18.75	-1.099	5.30
$pm-ad_2$	46	2.5	20.2	14.65	0.745	3.87	14.98	-1.141	4.79
$pm-ad_3$	47	15.4	28.1	20.57	0.602	3.13	9.79	0.429	2.87
$tu-ad_3$	48	2.4	11.8	6.95	0.455	2.36	5.58	-0.000	2.22
n_s-sn	49	46.3	64.0	54.18	0.993	5.16	26.63	0.290	2.03
n_s-prn	50	38.3	56.0	46.35	0.885	4.60	21.17	-0.373	2.43

UCLP

Table 30 (contd.)

Variable (N = 27)	NR	Range Min.	Max.	$\bar{x}$ Mean	Standard error of mean $s(\bar{x})$	Standard Deviation s	Variance s^2	Skewness /b1	Kurtosis b2
lnt to n-ss	51	6.6	11.4	8.74	0.256	1.33	1.77	0.331	2.24
s-n_s-unt	52	104.0	121.3	111.41	0.786	4.09	16.70	0.467	2.66
sto to NL	53	18.2	35.2	27.21	0.851	4.23	18.10	-0.191	2.87
s-n_s-ss_s	54	79.1	90.4	85.08	0.609	3.16	10.00	0.040	2.40
sn to lnt-l_s	55	6.5	14.7	10.09	0.401	2.09	4.35	0.470	2.56
ls to NCL	56	2.3	16.9	8.48	0.751	3.90	15.21	0.426	2.36
sto to ML	57	35.9	53.2	46.60	0.778	3.90	15.13	-1.010	5.85
s-n_s-sm_s	58	73.7	88.2	81.95	0.672	3.49	12.18	-0.314	2.70
sm_s to li-pg_s	59	2.4	9.5	6.30	0.311	1.62	2.61	-0.484	3.24
li to NCL	60	0.0	12.3	3.49	0.616	3.20	10.25	1.010	3.31
ss_s-n_s-sm_s	61	-5.6	10.4	3.13	0.748	3.80	15.11	-0.538	2.96
sto to ol_s	62	0.1	10.42	4.07	0.618	3.09	9.54	0.727	1.94
s-n_s-pg_s	63	75.5	91.0	84.18	0.743	3.86	14.92	-0.394	2.65
NFL/NCL	64	137.0	166.5	148.41	1.095	5.69	32.39	1.027	5.17

Similar data are shown for the cephalometric analysis of the various categories of clefting deformity. Table 28 for cleft lip (CL), Table 29 for cleft palate (CP) and Table 30 for unilateral cleft lip and palate subjects.

i) **Comparison of the cleft lip (CL) group and the control group**

The statistical data for this comparison are shown in Table 31. Few statistically significant differences between the 64 linear and angular variables were shown.

No significant differences were found in sagittal or vertical bony jaw relationships. Mandibular length (pg-tgo) was 5.2 mm less in the cleft lip category which was significantly different ($p<0.01$) when compared to the control group. The long axis of the upper central incisor (IL_s) to the maxillary plane (NL) in the cleft group was 97.0° which was 12.7° less than the mean value of 109.7° for the control group and was statistically significant ($p<0.001$).

Significant differences were found in the soft tissue morphology of the upper lip of the cleft lip (CL) subjects when comparisons were made with the control group.

The nasal protrusion ($s\text{-}n_s\text{-}unt$) was smaller in the cleft sample than in the control group. This was 113.6° for the cleft lip (CL) subjects, and 119.3° for the control, the difference being

TABLE 31

t-tests cleft lip and control

CL

Variable		Number of cases	$\bar{x}$ Mean	Standard Deviation	Standard Error	Value of F	2-Tail Prob.	Value of t	Degrees of Freedom	2-Tail Prob.
n-s	Cleft Lip	15	70.34	3.204	0.827	1.50	0.421	-0.88	51	0.382
	Control	38	71.35	3.922	0.636					
n-sp	Cleft Lip	15	50.13	5.410	1.397	1.43	0.378	-1.22	51	0.227
	Control	38	51.91	4.526	0.734					
n-gn	Cleft Lip	15	114.37	10.726	2.769	1.13	0.738	-0.92	51	0.362
	Control	38	117.25	10.106	1.639					
s-ba	Cleft Lip	15	46.24	4.273	1.103	1.16	0.687	-0.29	51	0.771
	Control	38	46.60	3.966	0.643					
a-ar	Cleft Lip	15	34.65	4.739	1.223	1.07	0.824	-0.24	51	0.813
	Control	38	34.98	4.577	0.743					
s-pm	Cleft Lip	15	45.58	5.118	1.322	1.32	0.483	-1.82	51	0.075
	Control	38	48.15	4.452	0.722					
s-tgo	Cleft Lip	15	76.57	9.836	2.540	1.38	0.419	-0.07	51	0.948
	Control	38	76.74	8.361	1.356					
sp-gn	Cleft Lip	15	66.51	8.332	2.151	1.55	0.286	-0.47	51	0.637
	Control	38	67.55	6.702	1.087					
ar-tgo	Cleft Lip	15	47.20	6.377	1.647	1.20	0.737	0.52	51	0.603
	Control	38	46.11	6.990	1.134					

CL

Table 31 (contd.)

Variable		Number of cases	$\overline{x}$ Mean	Standard Deviation	Standard Error	Value of F	2-Tail Prob.	Value of t	Degrees of Freedom	2-Tail Prob.
sp-pm	Cleft Lip	15	54.04	4.428	1.132	1.38	0.528	0.02	51	0.985
	Control	38	54.01	5.200	0.844					
ss-pm	Cleft Lip	15	49.62	2.853	0.737	2.45	0.075	-0.13	51	0.896
	Control	38	49.79	4.461	0.724					
pgn-cd	Cleft Lip	15	114.76	8.858	2.287	1.03	0.993	-1.61	51	0.114
	Control	38	119.17	9.009	1.462					
p g-tgo	Cleft Lip	15	71.00	5.601	1.446	1.24	0.689	-2.80	51	0.007**
	Control	38	76.28	6.231	1.011					
sp-is	Cleft Lip	15	27.97	4.805	1.241	1.80	0.154	-0.64	51	0.524
	Control	38	28.75	3.584	0.581					
ii-gn	Cleft Lip	15	40.30	3.921	1.012	1.20	0.629	-1.38	51	0.174
	Control	38	41.85	3.576	0.580					
n-s-ba	Cleft Lip	15	133.30	3.867	0.998	2.20	0.114	1.62	51	0.112
	Control	38	130.68	5.739	0.931					
n-s-ar	Cleft Lip	15	125.81	4.420	1.141	1.58	0.360	1.46	51	0.152
	Control	38	123.47	5.556	0.901					
pm-s-ba	Cleft Lip	15	61.86	5.334	1.377	1.68	0.299	0.97	51	0.336
	Control	38	59.93	6.908	1.121					
s-n-sp	Cleft Lip	15	87.06	3.382	0.873	2.14	0.128	-0.57	51	0.570
	Control	38	87.86	4.945	0.802					
s-n-ss	Cleft Lip	15	81.75	3.065	0.791	1.78	0.249	-0.82	51	0.416
	Control	38	82.71	4.083	0.662					
s-n-sm	Cleft Lip	15	76.60	2.989	0.772	1.83	0.224	-1.97	51	0.054
	Control	38	78.87	4.046	0.656					

CL

Table 31 (contd.)

Variable		Number of cases	$\overline{x}$ Mean	Standard Deviation	Standard Error	Value of F	2-Tail Prob.	Value of t	Degrees of Freedom	2-Tail Prob.
s-n-pg	Cleft Lip	15	78.09	2.778	0.717	2.33	0.092	-1.61	51	0.113
	Control	38	80.01	4.238	0.688					
ss-n-sm	Cleft Lip	15	5.15	2.676	0.691	1.75	0.262	1.30	51	0.200
	Control	38	3.84	3.537	0.574					
ss-n-pg	Cleft Lip	15	3.66	3.221	0.832	1.64	0.323	0.81	51	0.424
	Control	38	2.70	4.120	0.668					
NSL/NL	Cleft Lip	15	7.25	3.315	0.856	1.47	0.339	0.49	51	0.626
	Control	38	6.82	2.731	0.443					
NSL/ML	Cleft Lip	15	32.64	5.421	1.400	1.81	0.230	-0.44	51	0.660
	Control	38	33.57	7.308	1.185					
NL/ML	Cleft Lip	15	25.39	6.752	1.743	1.13	0.838	-0.63	51	0.532
	Control	38	26.75	7.180	1.165					
NSL/MBL	Cleft Lip	15	55.88	3.820	0.986	1.88	0.206	-0.16	51	0.870
	Control	38	56.13	5.231	0.849					
ML/RL	Cleft Lip	15	130.22	5.816	1.502	1.39	0.521	0.49	51	0.626
	Control	38	129.24	6.847	1.111					
IL_s/NL	Cleft Lip	15	96.99	10.235	2.643	2.44	0.031	-5.38	51	0.000***
	Control	38	109.70	6.557	1.064					
IL_i - ML	Cleft Lip	15	87.18	7.764	2.005	1.50	0.417	-1.81	51	0.077
	Control	38	92.18	9.517	1.544					
oj	Cleft Lip	15	3.98	4.125	1.065	1.63	0.233	-0.57	51	0.568
	Control	38	4.60	3.231	0.524					

CL

Table 31 (contd.)

Variable		Number of cases	$\bar{x}$ Mean	Standard Deviation	Standard Error	Value of F	2-Tail Prob.	Value of t	Degrees of Freedom	2-Tail Prob.
ob	Cleft Lip	15	-1.01	4.216	1.089	2.65*	0.018	1.84	51	0.072
	Control	38	-2.76	2.592	0.421					
NSL/VER	Cleft Lip	15	94.89	5.142	1.328	1.39	0.516	0.55	51	0.488
	Control	38	93.93	6.063	0.984					
NL/VER	Cleft Lip	15	87.64	6.600	1.704	1.37	0.436	0.30	51	0.769
	Control	38	87.11	5.645	0.916					
NSL/OPT	Cleft Lip	15	96.80	8.278	2.137	1.00	0.944	0.83	51	0.413
	Control	38	94.71	8.271	1.342					
NSL/CVT	Cleft Lip	15	101.13	7.188	1.856	1.16	0.790	0.77	51	0.444
	Control	38	99.34	7.752	1.258					
NL/OPT	Cleft Lip	15	89.55	10.086	2.604	2.00	0.093	0.67	51	0.505
	Control	38	87.90	7.134	1.157					
NL/CVT	Cleft Lip	15	93.88	9.111	2.352	1.78	0.159	0.59	51	0.558
	Control	38	92.52	6.822	1.107					
OPT/HOR	Cleft Lip	15	88.10	6.919	1.786	1.05	0.963	-0.52	51	0.606
	Control	38	89.21	7.097	1.151					
CVT/HOR	Cleft Lip	15	83.77	5.836	1.507	1.39	0.520	-0.41	51	0.686
	Control	38	84.59	6.873	1.115					
FH/VER	Cleft Lip	15	86.18	3.969	1.025	1.94	0.184	1.17	51	0.246
	Control	38	84.34	5.524	0.896					
FH/OPT	Cleft Lip	15	88.08	8.352	2.157	1.24	0.580	1.25	51	0.216
	Control	38	85.13	7.501	1.217					
FH/CVT	Cleft Lip	15	92.41	7.440	1.921	1.16	0.682	1.24	51	0.222
	Control	38	89.75	6.897	1.119					

Table 31 (contd.)

CL

Variable		Number of cases	$\overline{x}$ Mean	Standard Deviation	Standard Error	Value of F	2-Tail Prob.	Value of t	Degrees of Freedom	2-Tail Prob.
$pm\text{-}ad_1$	Cleft Lip	15	20.89	4.834	1.248	1.04	0.985	0.47	51	0.638
	Control	38	20.18	4.928	0.799					
$pm\text{-}ad_2$	Cleft Lip	15	17.19	5.091	1.315	1.53	0.298	0.64	51	0.525
	Control	38	16.33	4.119	0.668					
$pm\text{-}ad_3$	Cleft Lip	15	21.07	3.539	0.914	1.03	0.995	0.26	51	0.793
	Control	38	20.78	3.598	0.584					
$tu\text{-}ad_3$	Cleft Lip	15	8.90	2.168	0.560	1.17	0.674	0.64	51	0.525
	Control	38	8.50	2.004	0.325					
$n_s\text{-}sn$	Cleft Lip	15	52.23	6.818	1.760	1.14	0.712	0.48	51	0.634
	Control	38	51.28	6.376	1.034					
$n_s\text{-}prn$	Cleft Lip	14	43.25	6.363	1.701	1.22	0.617	-0.25	48	0.802
	Control	36	43.72	5.768	0.961					
Int to n-ss	Cleft Lip	15	7.45	1.014	0.262	1.09	0.906	-0.79	51	0.431
	Control	38	7.70	1.058	0.172					
$s\text{-}n_s\text{-}unt$	Cleft Lip	14	113.61	3.919	1.047	1.47	0.462	-4.00	48	0.000***
	Control	36	119.34	4.755	0.792					
sto to NL	Cleft Lip	13	26.21	3.583	0.994	1.04	0.880	0.66	44	0.510
	Control	33	25.44	3.516	0.612					
$s\text{-}n_s\text{-}ss_s$	Cleft Lip	15	89.37	3.501	0.904	1.19	0.754	-3.66	51	0.001***
	Control	38	93.54	3.817	0.619					
sn to $Int\text{-}l_s$	Cleft Lip	14	8.22	2.155	0.576	2.29	0.051	0.26	48	0.794
	Control	36	8.08	1.425	0.237					
ls to NCL	Cleft Lip	15	5.79	6.015	1.553	4.36***	0.000	1.49	49	0.142
	Control	36	3.94	2.880	0.480					

Table 31 (contd.)

CL

Variable		Number of cases	$\bar{x}$ Mean	Standard Deviation	Standard Error	Value of F	2-Tail Prob.	Value of t	Degrees of Freedom	2-Tail Prob.
sto to ML	Cleft Lip	13	40.90	5.616	1.558	1.57	0.304	-2.93	44	0.005**
	Control	33	45.52	4.487	0.781					
$s\text{-}n_s\text{-}sm_s$	Cleft Lip	15	81.29	3.680	0.950	1.24	0.682	-3.21	51	0.002**
	Control	38	85.20	4.103	0.666					
sm_s to $li\text{-}pg_s$	Cleft Lip	15	6.47	1.798	0.464	1.26	0.558	2.29	51	0.026
	Control	38	5.31	1.603	0.260					
li to NCL	Cleft Lip	14	3.78	3.498	0.935	1.90	0.131	0.64	48	0.524
	Control	36	3.21	2.538	0.423					
$ss_s\text{-}n_s\text{-}sm_s$	Cleft Lip	15	8.08	2.494	0.644	1.86	0.212	-0.27	51	0.788
	Control	38	8.35	3.402	0.552					
sto to OL_s	Cleft Lip	13	2.70	2.410	0.668	1.17	0.811	-2.54	44	0.015*
	Control	33	4.82	2.601	0.453					
$s\text{-}n_s\text{-}pg_g$	Cleft Lip	15	84.02	3.808	0.983	1.24	0.692	-1.79	51	0.079
	Control	38	86.27	4.233	0.687					
NFL/NCL	Cleft Lip	14	148.46	6.386	1.707	1.10	0.781	1.33	48	0.191
	Control	36	145.89	6.087	1.014					

* $p \leq 0.05$

** $p \leq 0.01$

*** $p \leq 0.001$

statistically significant ($p<0.001$).

The upper lip position was found to be less protrusive ($s\text{-}n_s\text{-}ss_s$) in the cleft lip (CL) group. This angular measurement between a line from sella (s) to soft tissue nasion (ns) and from the deepest concavity of upper lip curvature (ss_s) was smaller in the cleft group (89.4°) than in the control (93.5°) ($p<0.001$). The lower lip height (sto to ML) in the cleft group was smaller, the measurement of the distance from the upper to the lower lip contact point (sto) to the mandibular plane (ML) being less in the cleft lip group (40.9 mm) than in the controls (45.5 mm) ($p<0.05$).

The point of contact in the vertical plane between the upper and the lower lip ($sto\text{-}OL_s$) was also affected; the contact point being lower down the upper incisal surface nearer the incisal edge for the cleft lip (CL) group than for the controls ($p<0.05$).

For craniofacial morphology there was a considerable degree of conformity between the cleft lip (CL) and the control group apart from the effects on the soft tissues around the area of the deformity, the upper incisor angulation and the length of the mandible.

For head posture, none of the differences were significant at the 5% level and no airway dimensions ($pm\text{-}ad_1$, $pm\text{-}ad_2$, $pm\text{-}ad_3$, $tu\text{-}ad_3$) showed significant differences.

ii) **Comparison of the cleft palate (CP) group and the control group**

The statistical data for this comparison are shown in Table 32. Significant diferences were found in prognathism and sagittal and vertical jaw relationships. The maxilla was less prognathic for all sagittal angular dimensions in the cleft palate group, i.e. s-n-sp ($p<0.01$), s-n-ss ($p<0.001$). The mean value for its overall length at a dental base level (sp-pm) was 59.4 mm which was 5.4 mm less than the mean value for the control group ($p<0.05$). A significant difference was also demonstrated for the dimension ss-pm ($p<0.001$) which is a measure of the arch length at the alveolar level.

The mandible was also found to be less prognathic in the cleft palate category when compared to the control group, s-n-sm ($p<0.01$), s-n-pg ($p<0.01$) and the relationship between the maxilla and mandible ss-n-sm demonstrated a tendency toward a skeletal class 3 dental base relationship. The mean angular value for this dimension in the cleft palate group was 1.6° and for the control group 3.8° ($p<0.05$). The length of the body of the mandible (pg-tgo) was less in the cleft palate group ($p<0.01$) as was the overall length from the head of the condyle to the chin point (pgn-cd) ($p<0.05$), and the ramus/body angle (ML/RL) was larger ($p<0.05$).

The relationship of the maxilla to the anterior cranial base differred significantly between the two groups, the palatal plane

TABLE 32

t-tests cleft palate and control

Variable		Number of cases	$\bar{x}$ Mean	Standard Deviation	Standard Error	Value of F	2-Tail Prob.	Value of t	Degrees of Freedom	2-Tail Prob.
n-s	Cleft Palate	19	70.40	4.495	1.031	1.31	0.470	-0.82	55	0.418
	Control	38	71.35	3.922	0.636					
n-sp	Cleft Palate	19	51.32	5.896	1.353	1.70	0.171	-0.42	55	0.674
	Control	38	51.91	4.526	0.734					
n-gn	Cleft Palate	19	115.90	13.939	3.198	1.90	0.097	-0.42	55	0.677
	Control	38	117.25	10.106	1.639					
s-ba	Cleft Palate	19	46.18	5.172	1.187	1.70	0.169	-0.34	55	0.738
	Control	38	46.60	3.966	0.643					
s-ar	Cleft Palate	19	34.00	5.465	1.254	1.43	0.354	-0.78	55	0.441
	Control	38	34.98	4.577	0.743					
s-pm	Cleft Palate	19	44.10	6.309	1.447	2.01	0.072	-2.81	55	0.007**
	Control	38	48.15	4.452	0.722					
s-tgo	Cleft Palate	19	73.15	8.148	1.869	1.005	0.937	-1.54	55	0.129
	Control	38	76.74	8.361	1.356					
sp-gn	Cleft Palate	19	66.27	9.269	2.126	1.91	0.094	-0.60	55	0.551
	Control	38	67.55	6.702	1.087					
ar-tgo	Cleft Palate	19	42.90	5.360	1.230	1.70	0.229	-1.76	55	0.084
	Control	38	46.11	6.990	1.134					

CP

Table 32 (contd.)

Variable		Number of cases	$\overline{x}$ Mean	Standard Deviation	Standard Error	Value of F	2-Tail Prob.	Value of t	Degrees of Freedom	2-Tail Prob.
sp-pm	Cleft Palate	19	59.43	4.193	0.962	1.54	0.330	-2.61	55	0.012*
	Control	38	54.01	5.200	0.844					
ss-pm	Cleft Palate	19	45.46	4.104	0.942	1.18	0.722	-3.55	55	0.001***
	Control	38	49.79	4.461	0.724					
pgn-cd	Cleft Palate	19	112.16	12.4044	2.846	1.90	0.099	-2.40	55	0.020*
	Control	38	119.17	9.009	1.462					
pg-tgo	Cleft Palate	19	69.68	9.169	2.104	2.17*	0.046	-3.16	55	0.003**
	Control	38	76.18	6.231	1.011					
sp-is	Cleft Palate	19	28.31	3.497	0.802	1.05	0.942	-0.44	55	0.659
	Control	38	28.75	3.584	0.581					
ii-gn	Cleft Palate	19	40.85	5.252	1.205	2.16*	0.047	-0.84	55	0.403
	Control	38	41.85	3.576	0.580					
n-s-ba	Cleft Palate	19	127.91	6.528	1.498	1.29	0.494	-1.65	55	0.106
	Control	38	130.68	5.739	0.931					
n-s-ar	Cleft Palate	19	121.30	6.129	1.406	1.22	0.596	-1.34	55	0.186
	Control	38	123.47	5.556	0.901					
pm-s-ba	Cleft Palate	19	57.87	7.119	1.633	1.06	0.846	-1.06	55	0.296
	Control	38	59.93	6.908	1.121					
s-n-sp	Cleft Palate	19	83.08	5.806	1.332	1.38	0.400	-3.25	55	0.002**
	Control	38	87.86	4.945	0.802					
s-n-ss	Cleft Palate	19	77.23	5.203	1.194	1.62	0.209	-4.36	55	0.000***
	Control	38	82.71	4.083	0.662					
s-n-sm	Cleft Palate	19	75.64	4.171	0.957	1.06	0.844	-2.81	55	0.007**
	Control	38	78.87	4.046	0.656					

CP

Table 32 (contd.)

Variable		Number of cases	$\bar{x}$ Mean	Standard Deviation	Standard Error	Value of F	2-Tail Prob.	Value of t	Degrees of Freedom	2-Tail Prob.
s-n-pg	Cleft Palate	19	76.83	4.066	0.933	1.09	0.877	-2.71	55	0.009**
	Control	38	80.01	4.238	0.688					
ss-n-sm	Cleft Palate	19	1.58	4.306	0.988	1.48	0.305	-2.11	55	0.040*
	Control	38	3.84	3.537	0.574					
ss-n-pg	Cleft Palate	19	0.40	4.404	1.010	1.14	0.709	-1.95	55	0.057
	Control	38	2.70	4.120	0.668					
NSL/NL	Cleft Palate	19	10.66	6.135	1.407	5.05	0.000	3.28	55	0.002**
	Control	38	6.82	2.731	0.443					
NSL/ML	Cleft Palate	19	37.42	5.030	1.154	2.11	0.092	2.07	55	0.044*
	Control	38	33.57	7.308	1.185					
NL/ML	Cleft Palate	19	26.77	6.441	1.478	1.24	0.635	0.01	55	0.993
	Control	38	26.75	7.180	1.165					
NSL/MBL	Cleft Palate	19	58.40	4.175	0.958	1.57	0.307	1.65	55	0.105
	Control	38	56.13	5.231	0.849					
ML/RL	Cleft Palate	19	133.18	6.476	1.486	1.12	0.824	2.08	55	0.042*
	Control	38	129.24	6.847	1.111					
IL_s/NL	Cleft Palate	19	106.72	6.701	1.537	1.04	0.878	-1.16	55	0.114
	Control	38	109.70	6.557	1.064					
IL_i/ML	Cleft Palate	19	82.91	6.134	1.407	2.41*	0.049	-3.85	55	0.000***
	Control	38	92.18	9.517	1.544					
oj	Cleft Palate	19	3.31	4.556	1.045	1.99	0.076	-1.23	55	0.225
	Control	38	4.60	3.231	0.524					

CP

Table 32 (contd.)

Variable		Number of cases	$\overline{x}$ Mean	Standard Deviation	Standard Error	Value of F	2-Tail Prob.	Value of t	Degrees of Freedom	2-Tail Prob.
ob	Cleft Palate	19	-1.87	2.447	0.561	1.12	0.817	-0.15	55	0.880
	Control	38	-2.76	2.592	0.421					
NSL/VER	Cleft Palate	19	94.64	3.856	0.885	2.47	0.043	0.465	55	0.644
	Control	38	93.93	6.063	0.984					
NL/VER	Cleft Palate	19	83.98	6.627	1.520	1.38	0.400	-1.86	55	0.068
	Control	38	87.11	5.645	0.916					
NSL/OPT	Cleft Palate	19	94.53	9.786	2.245	1.40	0.378	0.83	51	0.413
	Control	38	94.71	8.271	1.342					
NSL/CVT	Cleft Palate	19	99.83	8.943	2.052	1.33	0.451	0.21	55	0.833
	Control	38	99.34	7.752	1.258					
NL/OPT	Cleft Palate	19	83.87	11.423	2.621	2.56*	0.015	-1.63	55	0.108
	Control	38	87.90	7.134	1.157					
NL/CVT	Cleft Palate	19	89.17	10.405	2.387	2.33*	0.029	-1.46	55	0.150
	Control	38	92.52	6.822	1.107					
OPT/HOR	Cleft Palate	19	90.11	11.101	2.547	2.45*	0.021	0.37	55	0.713
	Control	38	89.21	7.097	1.151					
CVT/HOR	Cleft Palate	19	84.81	10.129	2.324	2.17*	0.045	0.10	55	0.922
	Control	38	84.59	6.873	1.115					
FH/VER	Cleft Palate	19	85.32	4.780	1.097	1.34	0.519	0.66	55	0.510
	Control	38	84.34	5.524	0.896					
FH/OPT	Cleft Palate	19	85.21	9.801	2.248	1.71	0.166	0.04	55	0.970
	Control	38	85.13	7.501	1.217					
FH/CVT	Cleft Palate	19	90.51	9.013	2.068	1.71	0.166	0.35	55	0.725
	Control	38	89.75	6.897	1.119					

CP

Table 32 (contd.)

Variable		Number of cases	$\bar{x}$ Mean	Standard Deviation	Standard Error	Value of F	2-Tail Prob.	Value of t	Degrees of Freedom	2-Tail Prob.
$pm\text{-}ad_1$	Cleft Palate	19	17.60	3.282	0.753	2.26	0.068	-2.07	55	0.043*
	Control	38	20.18	4.928	0.799					
$pm\text{-}ad_2$	Cleft Palate	19	14.05	3.338	0.766	1.52	0.342	-2.09	55	0.041*
	Control	38	16.33	4.119	0.668					
$pm\text{-}ad_3$	Cleft Palate	19	18.28	3.941	0.904	1.20	0.621	-2.40	55	0.020*
	Control	38	20.78	3.598	0.584					
$tu\text{-}ad_3$	Cleft Palate	19	8.22	2.035	0.467	1.03	0.903	-0.49	55	0.627
	Control	38	8.50	2.004	0.325					
$n_s\text{-}sn$	Cleft Palate	19	52.54	8.017	1.839	1.58	0.234	0.64	55	0.522
	Control	38	51.28	6.376	1.034					
$n_s\text{-}prn$	Cleft Palate	19	44.60	7.656	1.756	1.76	0.148	0.48	53	0.633
	Control	36	43.72	5.768	0.961					
lnt to n-ss	Cleft Palate	19	8.11	1.522	0.349	2.07	0.061	1.17	55	0.246
	Control	38	7.70	1.058	0.172					
$s\text{-}n_s\text{-}unt$	Cleft Palate	19	113.40	5.222	1.198	1.21	0.616	-4.26	53	0.000***
	Control	36	119.34	4.755	0.792					
sto to NL	Cleft Palate	15	25.71	4.707	1215	1.79	0.170	0.23	46	0.822
	Control	33	25.44	3.516	0.612					
$s\text{-}n_s\text{-}ss_s$	Cleft Palate	19	89.00	4.530	1.039	1.41	0.370	-4.06	55	0.000***
	Control	38	93.54	3.817	0.619					
sn to $lnt\text{-}l_s$	Cleft Palate	19	7.67	1.100	0.252	1.68	0.243	-1.09	53	0.281
	Control	36	8.08	1.425	0.237					
ls to NCL	Cleft Palate	19	3.910	3.293	0.755	1.31	0.485	-0.04	53	0.968
	Control	36	3.94	2.880	0.480					

CP

Table 32 (contd.)

Variable		Number of cases	$\overline{x}$ Mean	Standard Deviation	Standard Error	Value of F	2-Tail Prob.	Value of t	Degrees of Freedom	2-Tail Prob.
sto to ML	Cleft Palate	15	44.00	6.997	1.807	2.43	0.037	-0.91	46	0.367
	Control	33	45.52	4.487	0.781					
$s\text{-}n_s\text{-}sm_s$	Cleft Palate	19	81.39	4.069	0.934	1.02	1.000	-3.31	55	0.002**
	Control	38	85.20	4.103	0.666					
sm_s to $li\text{-}pg_s$	Cleft Palate	19	4.66	1.257	0.288	1.63	0.271	-1.54	55	0.128
	Control	38	5.31	1.603	0.260					
li to NCL	Cleft Palate	19	2.65	2.443	0.561	1.08	0.890	-0.79	53	0.434
	Control	36	3.21	2.538	0.423					
$ss_s\text{-}n_s\text{-}sm_s$	Cleft Palate	19	7.53	3.603	0.827	1.12	0.741	-0.84	55	0.403
	Control	38	8.35	3.402	0.552					
sto to OL_s	Cleft Palate	15	4.27	2.378	0.614	1.20	0.743	-0.70	46	0.489
	Control	33	4.82	2.601	0.453					
$s\text{-}n_s\text{-}pg_s$	Cleft Palate	19	82.44	4.013	0.921	1.11	0.833	-3.28	55	0.002**
	Control	38	86.27	4.233	0.687					
NFL/NCL	Cleft Palate	19	148.42	4.629	1.062	1.73	0.217	-0.29	53	0.772
	Control	36	145.89	6.087	1.014					

* $p \leq 0.05$

** $p \leq 0.01$

*** $p \leq 0.001$

(NL) being more inclined to the nasion to sella line (NSL) in the cleft palate group ($p<0.01$). This inclination resulted in a smaller vertical dimension to the posterior nasal cavity (s-pm) ($p<0.01$), with a smaller pharyngeal airway dimensions ($pm\text{-}ad_1$, $pm\text{-}ad_2$, $pm\text{-}ad_3$) ($p<0.05$) than in the control.

The inclination of the mandibular plane to the anterior cranial base (NSL/ML) also differed significantly ($p<0.05$) from the controls and a marked retroclination of lower incisors was seen in the cleft palate group when compared to the control ($p<0.001$). The mean lower incisor angulation (IL_i/ML) for the control group was 92.2° and the mean angulation for the cleft palate group was 82.9°, a difference of 9.3°.

The effect of the cleft palate on the sagittal jaw relationship is also reflected in the soft tissue differences that were seen.

The nasal protrusion ($s\text{-}n_s\text{-}unt$) in the cleft palate group (CP) was smaller. This was 113.4° for cleft palate (CP) subjects and 119.3° for the controls ($p<0.001$).

The soft tissues overlying the most anterior part of maxilla and mandible were less protrusive for the cleft palate group (CP) than the controls. For the maxilla this angular dimension ($s\text{-}n_s\text{-}ss_s$) was 88.9° which was 4.4° less than that of the control group which was 93.5° ($p<0.001$).

The soft tissue protrusive dimensions for the mandible ($s-n_s-sm_s$, $s-n_s-pg_s$) were 3.8° and 3.9° smaller, respectively ($p<0.01$).

Subjects with clefts of the palate (CP) demonstrated a marked maxillary retrognathism, less protrusive upper lip with shorter dental base and arch length with an upwards inclination of the palatal plane with smaller size of airway dimension and clivus length.

The airway dimension $pm-ad_1$ for the cleft palate (CP) group was 17.6 mm and for the control 20.2 mm which was 2.6 mm less; the dimension $pm-ad_2$ for the cleft palate group was 14.1 mm and for the control 16.3 mm, a difference of 2.2 mm; and the dimension $pm-ad_3$ for the cleft palate group was 18.2 mm and for the control 20.8 mm, a difference of 2.6 mm. These comparisons revealed differences significant at the 5% level between the cleft palate subjects and the control sample.

iii) **Comparison of the unilateral cleft lip and palate (UCLP) group and the controls**

The statistical data for this comparison are shown in Table 33.

More widespread effects of the clefting deformity were seen when the data for the unilateral cleft lip and palate group were compared to the controls.

TABLE 33

t-tests unilateral cleft lip and palate and control

Variable		Number of cases	$\bar{x}$ Mean	Standard Deviation	Standard Error	Value of F	2-Tail Prob.	Value of t	Degrees of Freedom	2-Tail Prob.
n-s	UCLP	27	72.38	3.613	0.695	1.18	0.670	1.08	63	0.283
	Control	38	71.35	3.922	0.636					
n-sp	UCLP	27	53.80	4.972	0.957	1.21	0.590	1.59	63	0.117
	Control	38	51.91	4.526	0.734					
n-gn	UCLP	27	124.60	19.690	1.865	1.09	0.835	2.94	63	0.005**
	Control	38	117.25	10.106	1.639					
s-ba	UCLP	27	49.19	3.279	0.631	1.46	0.314	2.78	63	0.007**
	Control	38	46.60	3.966	0.643					
s-ar	UCLP	27	36.78	3.462	0.666	1.75	0.140	1.72	63	0.091
	Control	38	34.99	4.577	0.743					
s-pm	UCLP	27	45.83	4.801	0.924	1.16	0.662	-2.00	63	0.050*
	Control	38	48.15	4.452	0.722					
s-tg	UCLP	27	80.40	8.555	1.646	1.055	0.883	1.72	63	0.090
	Control	38	76.74	8.361	1.356					
sp-gn	UCLP	27	72.00	6.458	1.243	1.08	0.855	2.68	63	0.009**
	Control	38	67.55	6.702	1.087					
ar-tgo	UCLP	27	48.20	6.736	1.296	1.08	0.857	1.206	63	0.234
	Control	38	46.11	6.990	1.134					

UCLP

Table 33 (contd.)

Variable		Number of cases	$\bar{x}$ Mean	Standard Deviation	Standard Error	Value of F	2-Tail Prob.	Value of t	Degrees of Freedom	2-Tail Prob.
sp-pm	UCLP	27	53.48	4.816	0.927	1.17	0.692	-0.42	63	0.678
	Control	38	54.01	5.200	0.844					
ss-pm	UCLP	27	47.48	4.383	0.844	1.04	0.940	-2.07	63	0.042*
	Control	38	49.79	4.461	0.724					
pgn-cd	UCLP	27	122.59	9.100	1.751	1.02	0.939	1.50	63	0.138
	Control	38	119.17	9.009	1.462					
pg-tgo	UCLP	27	75.33	5.488	1.056	1.29	0.504	-0.57	63	0.573
	Control	38	76.18	6.231	1.011					
sp-is	UCLP	27	29.84	2.938	0.565	1.49	0.292	1.30	63	0.197
	Control	38	28.75	3.584	0.581					
ii-gn	UCLP	27	44.37	3.825	0.736	1.14	0.695	2.73	63	0.008**
	Control	38	41.85	3.576	0.580					
n-s-ba	UCLP	27	130.80	6.603	1.271	1.32	0.427	0.01	63	0.989
	Control	38	130.68	5.739	0.931					
n-s-ar	UCLP	27	125.40	6.224	1.198	1.25	0.518	1.32	63	0.193
	Control	38	123.47	5.556	0.901					
pm-s-ba	UCLP	27	55.43	4.873	0.938	2.01	0.066	-2.91	63	0.005**
	Control	38	59.93	6.908	1.121					
s-n-sp	UCLP	27	81.39	5.559	1.070	1.26	0.5905	-4.94	63	0.000***
	Control	38	87.86	4.945	0.802					
s-n-ss	UCLP	27	75.14	4.699	0.904	1.32	0.426	-6.92	63	0.000***
	Control	38	82.71	4.083	0.662					
s-n-sm	UCLP	27	75.50	3.197	0.754	1.07	0.876	-3.36	63	0.001***
	Control	38	78.87	4.046	0.656					

UCLP

Table 33 (contd.)

Variable		Number of cases	$\bar{x}$ Mean	Standard Deviation	Standard Error	Value of F	2-Tail Prob.	Value of t	Degrees of Freedom	2-Tail Prob.
s-n-pg	UCLP	27	77.15	4.058	0.781	1.09	0.829	-2.72	63	0.008**
	Control	38	80.01	4.238	0.688					
ss-n-sm	UCLP	27	-0.36	4.313	0.830	1.49	0.263	-4.30	63	0.000***
	Control	38	3.84	3.537	0.574					
ss-n-pg	UCLP	27	-2.02	4.684	0.901	1.29	0.466	-4.30	63	0.000***
	Control	38	2.70	4.120	0.668					
NSL/NL	UCLP	27	9.48	5.140	0.989	3.54***	0.000	2.708	63	0.009**
	Control	38	6.82	2.731	0.443					
NSL/ML	UCLP	27	36.50	6.215	1.196	1.38	0.392	1.69	63	0.096
	Control	38	33.57	7.308	1.185					
NL/ML	UCLP	27	27.02	6.459	1.243	1.24	0.579	0.151	63	0.878
	Control	38	26.75	7.180	1.165					
NSL/MBL	UCLP	27	59.10	4.697	0.904	1.24	0.572	2.35	63	0.022*
	Control	38	56.13	5.231	0.849					
ML/RL	UCLP	27	130.64	7.176	1.381	1.10	0.780	0.79	63	0.430
	Control	38	129.24	6.847	1.111					
IL_s/NL	UCLP	27	103.30	7.617	1.466	1.35	0.396	-3.63	63	0.001***
	Control	38	109.70	6.557	1.064					
IL_i/ML	UCLP	27	84.21	8.147	1.568	1.36	0.411	-3.53	63	0.001***
	Control	38	92.18	9.517	1.544					
oj	UCLP	27	-0.64	4.744	0.913	2.16*	0.032	-5.30	63	0.000***
	Control	38	4.60	3.231	0.524					

UCLP

Table 33 (contd.)

Variable		Number of cases	$\bar{x}$ Mean	Standard Deviation	Standard Error	Value of F	2-Tail Prob.	Value of t	Degrees of Freedom	2-Tail Prob.
ob	UCLP	27	-2.53	2.998	0.577	1.34	0.410	0.34	63	0.738
	Control	38	-2.76	2.592	0.421					
NSL/VER	UCLP	27	94.90	5.020	0.966	1.46	0.317	0.69	63	0.496
	Control	38	93.93	6.063	0.984					
NL/VER	UCLP	27	85.42	6.041	1.163	1.15	0.693	-1.15	63	0.254
	Control	38	87.11	5.645	0.916					
NSL/OPT	UCLP	27	100.07	8.222	1.582	1.01	0.991	2.58	63	0.012*
	Control	38	94.71	8.271	1.342					
NSL/CVT	UCLP	27	103.52	8.635	1.662	1.24	0.538	2.05	63	0.045*
	Control	38	99.34	7.752	1.258					
NL/OPT	UCLP	27	90.59	9.348	1.799	1.72	0.129	1.32	63	0.192
	Control	38	87.90	7.134	1.157					
NL/CVT	UCLP	27	94.05	19.987	1.922	2.14*	0.033	0.73	63	0.468
	Control	38	92.52	6.822	1.107					
OPT/HOR	UCLP	27	84.83	16.782	1.305	1.09	0.821	-2.50	63	0.015*
	Control	38	89.21	7.097	1.151					
CVT/HOR	UCLP	27	81.38	17.417	1.427	1.16	0.660	-1.80	63	0.077
	Control	38	84.59	6.873	1.115					
FH/VER	UCLP	27	85.21	4.651	0.895	1.41	0.363	0.67	63	0.506
	Control	38	84.34	5.524	0.896					
FH/OPT	UCLP	27	90.38	8.167	1.572	1.19	0.625	2.68	63	0.009**
	Control	38	85.13	7.501	1.217					
FH/CVT	UCLP	27	93.83	8.583	1.652	1.55	0.218	2.12	63	0.038*
	Control	38	89.75	6.897	1.119					

UCLP

Table 33 (contd.)

Variable		Number of cases	$\bar{x}$ Mean	Standard Deviation	Standard Error	Value of F	2-Tail Prob.	Value of t	Degrees of Freedom	2-Tail Prob.
$pm\text{-}ad_1$	UCLP	27	17.96	4.330	0.833	1.30	0.495	-1.88	63	0.064
	Control	38	20.18	4.928	0.799					
$pm\text{-}ad_2$	UCLP	27	14.65	3.870	0.745	1.13	0.750	-1.66	63	0.101
	Control	38	16.33	4.119	0.668					
$pm\text{-}ad_3$	UCLP	27	20.57	3.130	0.602	1.32	0.461	-0.24	63	0.812
	Control	38	20.78	3.598	0.584					
$tu\text{-}ad_3$	UCLP	27	6.95	2.353	0.455	1.39	0.352	-2.84	63	0.006**
	Control	38	8.50	2.004	0.325					
$n_s\text{-}sn$	UCLP	27	54.18	5.160	0.993	1.53	0.262	1.95	63	0.055
	Control	38	51.28	6.376	1.034					
$n_s\text{-}prn$	UCLP	27	46.35	4.601	0.885	1.57	0.235	1.95	61	0.056
	Control	36	43.72	5.768	0.961					
lnt to n-ss	UCLP	27	8.74	1.330	0.256	1.58	0.197	3.51	63	0.001**
	Control	38	7.70	1.058	0.172					
$s\text{-}n_s\text{-}unt$	UCLP	27	111.41	4.086	0.786	1.35	0.426	-6.95	61	0.000***
	Control	36	119.34	4.755	0.792					
sto to NL	UCLP	25	27.21	4.253	0.851	1.46	0.312	1.733	56	0.089
	Control	33	25.44	3.516	0.612					
$s\text{-}n_s\text{-}ss_s$	UCLP	27	85.08	3.162	0.609	1.46	0.319	-9.44	63	0.000***
	Control	38	93.54	3.817	0.619					
sn to $lnt\text{-}l_s$	UCLP	27	10.09	2.086	0.401	2.14*	0.036	4.54	61	0.000***
	Control	36	8.08	1.425	0.237					
ls to NCL	UCLP	27	8.48	3.900	0.751	1.83	0.094	5.31	61	0.000***
	Control	36	3.94	2.880	0.480					

UCLP

Table 33 (contd.)

Variable		Number of cases	$\bar{x}$ Mean	Standard Deviation	Standard Error	Value of F	2-Tail Prob.	Value of t	Degrees of Freedom	2-Tail Prob.
sto to ML	UCLP	25	46.60	3.889	0.778	1.33	0.473	0.96	56	0.343
	Control	33	45.52	4.487	0.781					
$s\text{-}n_s\text{-}sm_s$	UCLP	27	81.95	3.490	0.672	1.38	0.392	-3.34	63	0.001***
	Control	38	85.20	4.103	0.666					
sm_s to $li\text{-}pg_s$	UCLP	27	6.30	1.616	0.311	1.02	0.947	2.44	63	0.017
	Control	38	5.31	1.603	0.260					
li to NCL	UCLP	27	3.49	3.202	0.616	1.59	0.198	0.38	61	0.702
	Control	36	3.21	2.538	0.423					
$ss_s\text{-}n_s\text{-}sm_s$	UCLP	27	3.13	3.887	0.748	1.31	0.449	-5.74	63	0.000***
	Control	38	8.35	3.402	0.552					
sto to OL_s	UCLP	25	4.07	2.089	0.618	1.41	0.360	-1.901	56	0.319
	Control	33	4.82	2.601	0.453					
$s\text{-}n_s\text{-}pg_s$	UCLP	27	84.18	3.863	0.743	1.20	0.633	-2.04	63	0.046*
	Control	38	86.27	4.233	0.687					
NFL/NCL	UCLP	27	148.41	5.691	1.095	1.14	0.730	1.67	61	0.099
	Control	36	145.89	6.087	1.014					

* $p \leq 0.05$

** $p \leq 0.01$

*** $p \leq 0.001$

Both maxilla and mandible were more retrognathic to the anterior cranial base than the controls, the maxilla more than the mandible, thus the sagittal jaw relationship (ss-n-sm) was distinctly Class 3, having a mean value of -0.4° when compared to the mean of the control group of 3.4°, a difference of 4.2° ($p<0.001$).

The overall face height was larger (n-gn) ($p<0.01$), most of this difference being in the lower face height (sp-gn) ($p<0.01$). Palatal inclination was affected in the cleft group, the dimension s-pm being smaller ($p<0.05$) indicating the posterior part of the palate was situated at a higher level in the unilateral cleft lip and palate group than in the controls (NSL/NL; $p<0.01$). This was reflected in the angulation of the palatal plane (NL) to the nasion sella line (NSL) which was larger in the cleft group to 9.5° ($p<0.01$).

Some effect was seen on clivus length (s-ba) which was larger in the unilateral cleft lip and palate (UCLP) group ($p<0.01$). This had an effect on the relationship of basion (ba) to posterior nasal spine (pm), a reduction in nasopharyngeal space measured by the angle pm-s-ba ($p<0.01$), and airway dimension tu-ad_3 ($p<0.01$).

At a dental level, highly significant differences were seen between the clefts group and the controls. This was perhaps most marked in overjet measurement, the mean of which was -0.6 mm for the cleft group and 4.6 mm for the control, a difference of 5.2 mm which was highly significant ($P<0.001$). The long axes of the upper incisor (IL_s-NL) to the palatal plane, and the long axis of the lower incisor (IL_i-ML) to the mandibular plane were both grossly affected by the deformity when compared to the control group ($P<0.001$), and the distance of the lower incisor tip to the lower border of the mandible (ii-gn) was larger than in the control ($p<0.01$).

Regarding head posture measurements cranio-cervical angulation was 5.4° larger for NSL/OPT, and 4.2° for NSL/CVT, both significant at the 5% level ($p<0.05$). This difference in head posture was reflected in differences in angulation of the Frankfort plane (FH) to cervical vertebral tangent (CVT) and odontoid process tangent (OPT). In the unilateral cleft lip and palate group (UCLP) FH/OPT was 5.2° larger than the controls ($p<0.01$) and FH/CVT 4.1° ($p<0.05$).

Gross soft tissue effects of the unilateral cleft deformity were shown for many of the soft tissue linear and angular dimensions when compared to the controls.

Nasal protrusion (s-n_s-unt) was smaller in the unilateral cleft lip and palate group than the controls ($p<0.001$), as was upper lip protrusion (s-n_s-ss_s) ($p<0.001$) measured at the deepest concavity of the upper lip profile. A similar difference in mandibular soft tissue protrusion was seen (s-n_s-sm_s) ($p<0.001$); (s-n_s-pg_s ($p<0.05$)

and the overall sagittal relationship between maxillary and mandibular soft tissues (ss_s-n_s-sm_s) was markedly smaller. This was 8.3° in the control group and 3.1° in theunilateral cleft lip and palate (UCLP) group ($p<0.001$).

A deeper and reduced naso-labial curvature (sn to lnt-l_s was noted in the cleft group (UCLP). The distance from the deepest point in the naso-labial curvature (sn) to the nose to upper lip tangent was smaller, being 10.1 mm in the cleft group and 8.1 mm in the control ($p<0.001$).

The prominence of the upper lip (ls) to the nose-chin line (NCL) was also markedly smaller (ls to NCL). This had a mean value for the unilateral cleft lip and palate group (UCLP) of 8.5 mm and for the control 3.9 mm ($p<0.001$). Lower lip protrusion was not smaller as expected but the mento-labial fold measured at (sm_s to li-pg_s) was larger when compared to the controls ($p<0.05$).

The overall analysis of the craniofacial structures in the cleft lip and palate subjects (UCLP) demonstrated more widespread differences in morphology of both the bony and soft tissue components. Overall face height was markedly larger with maxillary and mandibular retrognathism, Class III dental base relationship and negative overjet. An upward tilt of the palatal plane (NL) and a smaller nasopharyngeal space and airway dimension were demonstrated together with a larger cranio-cervical angulation for both NSL/CVT and NSL/OPT when compared to the control group.

Gross soft tissue changes affected nasal and upper lip protrusion with a marked naso-labial curvature and increased mento-labial fold.

TABLE 34

Differences between the means of the controls and the means of each cleft category

Variable	Difference Control-UCLP	Difference Control-CP	Difference Control-CL
n-s	-1.03	0.95	1.00
n-sp	-1.89	0.55	1.79
n-gn	-7.35**	1.35	2.88
s-ba	-2.59**	0.42	0.37
s-ar	-1.80	1.06	0.33
s-pm	2.32*	4.06**	2.57
s-tg	-3.66	3.59	0.17
sp-gn	-4.45**	1.28	1.04
ar-tgo	-2.09	3.21	-1.09
sp-pm	0.53	-5.41*	-0.03
ss-pm	2.31*	4.33***	0.17
pgn-cd	-3.42	7.01*	4.40
pg-tgo	0.85	6.50**	5.28**
sp-is	-1.09	0.44	0.78
ii-gn	-2.52**	1.00	1.55
n-s-ba	-0.11	2.78	-2.62
n-s-ar	-1.93	2.17	2.33
pm-s-ba	4.50**	2.07	1.93
s-n-sp	6.47***	4.78**	0.80
s-n-ss	7.57***	5.48***	0.96
s-n-sm	3.37***	3.23**	2.27
s-n-pg	2.86**	3.18**	1.92
ss-n-sm	4.20***	2.26*	-1.31
ss-n-pg	4.72***	2.30	-0.96
NSL/NL	-2.66**	3.84**	-0.43
NSL/ML	2.92	-3.85*	0.93
NL/ML	-0.27	-0.02	1.35
NSL/MBL	-2.96*	-2.27	0.25
ML/RL	-1.40	-3.94*	-0.98
IL$_s$/NL	6.40***	2.98	12.70***
IL$_i$/ML	7.97***	9.27***	5.00
oj	5.24***	1.29	0.58
ob	-0.23	-0.89	-1.75
NSL/VER	-0.97	-0.71	-0.96
NL/VER	1.69	3.13	-0.53
NSL/OPT	-5.36*	0.18	-2.09
NSL/CVT	-4.18*	-0.49	-1.79
NL/OPT	-2.69	4.03	-1.65
NL/CVT	-1.53	3.35	-1.36
OPT/HOR	4.38*	-0.90	1.11
CVT/HOR	3.21	-0.22	0.82
FH/VER	-1.47	-0.98	-1.84
FH/OPT	-5.25**	-0.08	-2.95
FH/CVT	-4.08	-0.76	-2.66
pm-ad$_1$	2.22	2.58*	-0.71
pm-ad$_2$	1.68	2.28*	-0.86
pm-ad$_3$	0.21	2.50*	-0.29
tu-ad$_3$	1.55**	0.28	-0.40
n$_s$-sn	-2.90	-1.25	-0.95
n$_s$-prn	-2.64	-0.88	0.48
lnt to n-ss	-1.04**	-0.40	0.25
s-n$_s$-unt	7.93***	5.95***	5.73***
sto to NL	-1.76	-0.27	-0.76
s-n$_s$-ss$_s$	8.46***	4.63***	4.17***
sn to lnt-l$_s$	-2.01***	0.41	-0.13
ls to NCL	-4.54***	0.03	-1.85
sto to ML	-1.08	1.52	4.62**
s-n$_s$-sm$_s$	3.25***	3.81**	3.91**
sm$_s$ to li-pg$_s$	-0.99	0.65	-1.10
li to NCL	-0.28	0.56	-0.50
ss$_s$-n$_s$-sm$_s$	5.22***	0.82	-0.26
sto to OL$_s$	0.75	0.55	2.12*
s-n$_s$-pg$_s$	2.09*	3.83**	2.25
NFL/NCL	-2.52	-2.53	-2.57

* $p<0.05$
** $p<0.01$
*** $p<0.001$

Linear measurements in millimetres
Angular measurements in degrees

Discussion of Cephalometric Results

i) Comparison of the cleft lip (CL) and the control group

In craniofacial morphology there was a considerable degree of conformity between the cleft lip sample (CL) and the control group. This conformity has been reported in previous investigations (Krogman et al 1975). Ross (1965) reported a greater similarity between non-cleft controls and subjects with cleft lip (CL) than to cleft palate (CP) or unilateral and bilateral clefts of lip and palate (UCLP, BCLP). In an investigation of craniofacial morphology of subjects with clefts of the lip (Dahl 1970) similar findings were seen, however,no soft tissue measurements were made. This investigation reported in detail the differences, which included a smaller mandibular length and retroclination of upper incisor, the mandibular length being 5.3 mm less and upper incisors retroclined by 12.7° on average than the control (Table 34). A smaller length of clivus (s-ba) reported by Dahl (1970) was not, however, demonstrated.

In the present study, nasal protrusion was smaller, upper lip length was larger and less protrusive, and lower lip height was smaller and less protrusive.

Dahl (1970) identified a shorter standing height and smaller head size for subjects with clefts of the lip (CL) which could explain the shorter mandible. The retroclination of upper incisors and the soft tissue disturbance around the defect reflect what is seen clinically. The upper lip is less protrusive, is longer and contains scar tissue. The contraction of scar tissue after the repair may exert a restraining force on nasal tip forward development. This would explain the less protrusive nose in the cleft group (CL) than the control. Significant differences were also noted for lower lip protrusion but this can be accounted for due to the smaller mandibular length for the cleft lip (CL) sample than the control group.

It was interesting to find that there were no more sagittal or vertical jaw discrepancies in the anomaly sample than the controls (Table 34). The scar tissue however seemed to have an effect on restraining forward nasal growth but it did not seem to affect maxillary position. Smaller alveolar prognathism, as described by Graber (1954), could not be demonstrated in the present study but the upper incisors were very retroclined.

The surgical repairs of the lip and alveolar deformities had been carried out by several different plastic surgeons but the effects of the repairs seemed to have little overall effect on craniofacial growth, apart from the local effects of the deformity on the upper lip and nose.

ii) **Comparison of the cleft palate (CP) and the control group**

A close similarity was found between the results of the analysis of the craniofacial variables in the present study with that of Dahl (1970).

No earlier accurate detailed morphological description of the craniofacial form in subjects with cleft palate (CP) was found in the literature before this study by Dahl (1970). The results of that investigation showed that posterior face height (s-pm) was smaller in the cleft palate sample when compared to the control group whereas anterior face height measurements (n-sp, sp-gn) were similar for both groups. The present study confirmed this and also supported the finding that the maxillary base inclined upwards and backwards (Table 34).

Significant differences were found in sagittal and vertical jaw relationships, a marked maxillary retrusion being present (s-n-ss) when compared to the control group ($p<0.001$), mandibular retrognathism (n-s-sm) was also present although not to such a marked degree as maxillary retrusion when compared to the controls ($p<0.01$). The relationship between the maxilla and mandible (ss-n-sm) was therefore affected in the cleft palate (CP) group caused by a greater maxillary retrusion than mandibular retrusion. It appears therefore that the repaired cleft deformity exerts some restraining effect on maxillary forward growth. Maxillary dental base length (sp-pm) and arch length (ss-pm) were both smaller.

The overall effect of the inclination of the palate and retruded position resulted in a smaller vertical dimension to the posterior nasal cavity with smaller pharyngeal airway dimensions (pm-ad_1, pm-ad_2, pm-ad_3) than the controls.

The overall restraint to forwards growth of the maxilla in the cleft palate (CP) sample was reflected in the markedly smaller nasal protrusion ($p<0.001$), maxillary retrusion ($p<0.001$) and compensatory lower incisor retroclination ($p<0.001$).

The soft tissues in subjects with cleft palate deformity reflect the underlying effect of the retrusive maxilla and mandible but are not involved in any surgical repair as the greatest forward extent of the cleft palate deformity is the incisive foramen.

iii) Comparison of the unilateral cleft lip and palate (UCLP) and the control group

Unilateral cleft lip and palate deformity has a more widespread effect on dental and jaw relationships, cranial base and soft tissues (Coccaro & Pruzansky 1965; Dahl & Kreiborg 1977). The continuity of the maxilla is breached by the congenital anomaly and unilateral nasal respiratory resistance is markedly greater on the cleft side ($p<0.001$). Subjects with unilateral clefts of the lip and palate (UCLP) have morphological characteristics common to both clefts of the lip (CL) and clefts of the palate (CP). The sagittal and vertical jaw relationships are disturbed. The maxilla and mandible are more retrognathic, and this is reflected in the soft tissue relationships to the bony matrix. The maxilla was found to be markedly more retrognathic than the mandible and together with the retroclined upper incisors accounted for the reverse overjet present. In the cleft palate (CP) sample, the upper incisors were retroclined on average by 9.3° yet achieved a positive overjet. The upper incisors in the unilateral cleft lip and palate (UCLP) sample were retroclined but in comparison by only 6.4° (Table 34), yet on average had a negative overjet to the mandibular incisors. This was as a result of the greater degree of maxillary retrognathia to the anterior cranial base in unilateral cleft lip and palate (UCLP), an indication of the greater restraining effect on maxillary forward growth by the scar tissue and the effects of the deformity (Moss 1956).

In this unilateral cleft palate category (UCLP) no observed change occurred to anterior face height. In the present study overall face height (n-gn) was greater, most of this increase occurring in lower face height (sp-gn). This finding is in agreement with the reported results of Dahl (1970) who observed a greater total face height in unilateral cleft lip and palate subjects.

More widespread effects of unilateral cleft lip and palate deformity (UCLP) to cranial base were also seen. Clivus length was larger and this had an effect on the relationship to posterior nasal spine and airway dimension.

C Results of Head Posture Measurements

Figure 17 shows the planes and angles used in the analysis of head posture. The values for NSL/VER, NL/VER, NSL/OPT, NSL/CVT, NL/OPT, NL/CVT, OPT/HOR, CVT/HOR, FH/VER, FH/OPT, FH/CVT are shown for the controls in Table 27, for cleft lip (CL) Table 28, for cleft palate (CP) Table 29 and for unilateral cleft lip and palate (UCLP) Table 30. The comparison of the values for each angular measurement of head posture in the control group with the cleft lip (CL) sample is shown in Table 31, with the cleft palate (CP) sample Table 32 and with the unilateral cleft lip and palate (UCLP) sample Table 33.

i) Comparison of the results of head posture measurements for the cleft lip (CL) sample and the controls

In the cleft lip sample (CL) greater values for cranio-cervical angulation were demonstrated (Table 31) but none of these differences, however, were significant at the 5% level.

Although small variations did occur between the other values recorded for head posture, none reached the conventional level of significance, the greatest difference recorded being 3.0° for FH/OPT (Cleft Lip [CL] = 88.08°, Control = 85.13°).

ii) **Comparison of the results of head posture measurements for the cleft palate (CP) sample and the controls**

Most of the angular measurements for head posture in the cleft palate (CP) sample (Table 32) were somewhat larger than the controls; for the angles NL/VER, NL/OPT, NL/CVT the measurements were larger by several degrees although not significant, the value for NL/VER approaching the 5% level of significance ($p=0.068$).

iii) **Comparison of the results of head posture measurements for the unilateral cleft lip and palate (UCLP) sample and the controls**

Head posture measurements for the unilateral cleft lip and palate (UCLP) sample and the control (Table 33) highlighted greater differences which were not shown in other categories of the deformity. Cranio-cervical angulations (NSL/OPT and NSL/CVT) were greater 5.4° for NSL/CVT and 4.2° for NSL/OPT when compared to the control group, both differences being significant at the 5% level ($p<0.05$). The angle FH/OPT was 5.2° greater than the control ($p<0.01$). All measurements recorded for the analysis of head posture showed greater values for the anomaly sample (UCLP) than the controls apart from the dimension OPT/HOR ($p<0.05$) which was smaller.

Discussion of Results of Head Posture Measurements

Scrutiny of the results of the analysis between the cleft lip category (CL) and the controls shows no significant change in cranio-cervical angulation measured at NSL/CVT and NSL/OPT.

The considerable degree of conformity that exists between the cleft lip sample and the controls for craniofacial morphology is also present for the analysis of head posture.

For the cleft palate (CP) sample, a greater angular difference was found for NL/VER, reaching the 5% level of significance.

In the cleft palate (CP) sample, the relationship of the maxilla to the anterior cranial base was altered when compared to the control sample, the palatal plane (NL) being more inclined to nasion sella line (NSL). This inclination which is associated with cleft palate (CP) deformity may account for the differences found for head posture measurements using the palatal plane (NL).

For the unilateral cleft lip and palate sample (UCLP) significantly greater measurements of cranio-cervical angulation (NSL/CVT, NSL/OPT) were found between the anomaly sample and the controls, which was reflected in significantly greater angles FH/CVT, FH/OPT. In the present study the angles selected to determine craniocervical angulation were NSL/CVT and NSL/OPT. These measurements have been utilised in previous studies (Siersbaek-Nielsen & Solow 1982; Solow et al 1984) and involve structures remote from the affected areas. Indeed, when angular values for head posture using the palatal plane (NL) are scrutinised, significant differences are detected which are due to the involvement of the deformity on the palate.

Measurements for bilateral nasal respiratory resistance for all categories of clefting deformity showed no significant differences when the two sides were compared to controls indicating some degree of compensation having taken place. It might therefore have been assumed that no significant differences would be found for head posture measurements for all categories of clefts and the control.

However, in unilateral cleft lip and palate (UCLP) significantly greater differences were seen for head posture measurements.

Smaller airway dimension would be expected in these subjects with raised head posture (Solow _et al_ 1984) but although airway dimension was smaller as measured at pm-ad_1, pm-ad_2 and pm-ad_3 none of these values were significantly smaller when compared to the controls. Since clefting deformity has a more widespread effect on other structures (Pashayan 1983), it may be that in this category of deformity (UCLP) head posture measurements may be affected by influence of the anomaly on cervical vertebral and cranial base structures. Indeed, in a previous study of cervical vertebral anomalies in subjects with cleft lip and palate (Sandham 1986), the results confirmed that cervical vertebral anomalies occurred significantly more often in a cleft sample than a control group.

D Analysis of Associations between Airway Dimension, Nasal Resistance, Head Posture and Face Height

Statistical Methods

The associations between the three groups of variables were expressed by correlation coefficients for the control group (Table 35) and each of the categories of clefts; cleft lip (CL) (Table 36), cleft palate (CP) (Table 37) and unilateral cleft lip and palate (UCLP) (Table 38). The statistical analyses were performed by the SPSS statistical programme package at the Edinburgh Regional Computing Centre (ERCC).

Correlation coefficients as a means of association is only valid when two sets of measurements form a normal two dimensional distribution. Rigorous tests for this are not available but a necessary condition is that the marginal one dimensional forms are normally distributed. This was examined by kurtosis and skewness for all distributions with only a few values being statistically significant.

Correlation tests are included for completeness being aware of the difficulties in application of the statistic to small numbers. Even so, statistically significant associations are found but interpreted with care.

TABLE 35

Correlations between face height, head posture and airway dimension in a control group

N = 38

	Face Height		Head Posture		Airway Adequacy				Nasal Resistance	
	n-sp	sp-gn	NL/ML	NSL/CVT	NSL/OPT	$pm\text{-}ad_1$	$pm\text{-}ad_2$	$pm\text{-}ad_3$	$tu\text{-}ad_3$	PNR(i)	PNR(e)
n-sp		0.63***	0.02	0.37*	0.35*	0.05	0.19	0.41**	0.05	-0.22	-0.17
sp-gn	0.63***		0.57***	0.43**	0.37**	0.14	0.33*	0.52***	0.02	-0.10	-0.04
NL/ML	0.02	0.57***		0.24	0.27	-0.12	-0.02	0.10	-0.25	0.22	0.24
NSL/CVT	0.37*	0.43**	0.24		0.94***	-0.13	-0.09	0.11	-0.33*	0.15	0.25
NSL/OPT	0.35*	0.37**	0.27	0.94***		-0.15	-0.14	0.09	-0.39**	0.12	0.19
$pm\text{-}ad_1$	0.05	0.14	-0.12	-0.13	-0.15		0.89***	0.73***	0.37**	-0.27	-0.30*
$pm\text{-}ad_2$	0.19	0.33*	-0.02	-0.09	-0.14	0.89***		0.82***	0.48***	-0.20	-0.22
$pm\text{-}ad_3$	0.41**	0.52***	0.10	0.11	0.09	0.73***	0.82***		0.30*	-0.14	-0.11
$tu\text{-}ad_3$	0.05	0.02	-0.25	-0.33*	-0.39**	0.37**	0.48***	0.30*		-0.35*	-0.35*
PNR(i)	-0.22	-0.10	0.22	0.15	0.12	-0.27	-0.20	-0.14	-0.35*		0.96***
PNR(e)	-0.17	-0.04	0.24	0.25	0.19	-0.30*	-0.22	-0.11	-0.35*	0.96***	

* $p \leq 0.05$

** $p \leq 0.01$

*** $p \leq 0.001$

TABLE 36

Correlations between face height, head posture and airway dimension in subjects with cleft lip (CL)

N = 15

	Face Height		Head Posture			Airway Adequacy				Nasal Resistance	
	n-sp	sp-gn	NL/ML	NSL/CVT	NSL/OPT	$pm\text{-}ad_1$	$pm\text{-}ad_2$	$pm\text{-}ad_3$	$tu\text{-}ad_3$	PNR(i)	PNR(e)
n-sp		0.38	-0.23	0.20	0.06	0.00	0.19	0.29	-0.16	0.28	0.33
sp-gn	0.38		0.56*	0.43	0.28	0.14	0.12	0.43	0.18	-0.02	-0.03
NL/ML	-0.23	0.56*		0.56*	0.58*	-0.06	-0.24	0.04	0.03	-0.13	-0.14
NSL/CVT	0.20	0.43	0.56*		0.94**	0.05	-0.13	0.09	-0.05	0.24	0.26
NSL/OPT	0.06	0.28	0.58*	0.94***		-0.15	-0.34	-0.10	-0.09	0.30	0.32
$pm\text{-}ad_1$	0.00	0.14	-0.06	0.05	-0.15		0.88***	0.71**	0.15	-0.32	-0.35
$pm\text{-}ad_2$	0.19	0.12	-0.24	-0.13	-0.34	0.88***		0.76***	0.24	-0.34	-0.37
$pm\text{-}ad_3$	0.29	0.43	0.04	0.09	-0.10	0.71**	0.76***		0.23	-0.21	-0.23
$tu\text{-}ad_3$	-0.16	0.18	0.03	-0.05	-0.09	0.15	0.25	0.23		-0.24	-0.28
PNR(i)	0.28	-0.02	-0.13	0.24	0.30	-0.32	-0.34	-0.21	-0.24		0.99***
PNR(e)	0.33	-0.03	-0.14	0.26	0.32	-0.35	-0.37	-0.23	-0.28	0.99***	

* $p \leq 0.05$

** $p \leq 0.01$

*** $p \leq 0.001$

TABLE 37

Correlations between face height, head posture and airway dimension in subjects with cleft palate (CP)

N = 19

	Face Height		Head Posture			Airway Adequacy			Nasal Resistance	
	n-sp	sp-gn	NL/ML	NSL/CVT	NSL/OPT	pm-ad_1	pm-ad_2	pm-ad_3	tu-ad_3	PNR(i)	PNR(e)
n-sp		0.42*	-0.05	0.44*	0.39*	0.47*	0.47*	0.39	0.66**	-0.23	-0.20
sp-gn	0.42*		0.54*	0.51*	0.41*	0.33	0.51*	0.57**	-0.02	-0.44	-0.37
NL/ML	-0.05	0.54*		0.26	0.26	0.10	0.34	0.52*	0.00	-0.59**	-0.49*
NSL/CVT	0.44*	0.51*	0.26		0.93***	0.15	0.01	0.27	-0.31	-0.24	-0.25
NSL/OPT	0.39*	0.41*	0.26	0.93***		0.23	0.03	0.31	-0.25	-0.43*	-0.45*
pm-ad_1	0.47*	0.33	0.10	0.15	0.23		0.73***	0.70***	0.09	-0.40*	-0.41*
pm-ad_2	0.47*	0.51*	0.34	0.01	0.03	0.73***		0.78***	0.31	-0.45*	-0.44*
pm-ad_3	0.39	0.57**	0.52*	0.27	0.31	0.70***	0.78***		0.10	-0.61**	-0.61**
tu-ad_3	0.66**	-0.02	0.00	-0.31	-0.25	0.09	0.31	0.10		-0.10	-0.09
PNR(i)	-0.23	-0.44*	-0.59**	-0.24	-0.43*	-0.40*	-0.45*	-0.61**	-0.10		0.98***
PNR(e)	-0.20	-0.37	-0.49*	-0.25	-0.45*	-0.41*	-0.44*	-0.61**	-0.09	0.98***	

* $p \leq 0.05$

** $p \leq 0.01$

*** $p \leq 0.001$

TABLE 38

Correlations between face height, head posture and airway dimension in subjects with unilateral cleft lip and palate (UCLP)

N = 27

	Face Height			Head Posture		Airway Adequacy				Nasal Resistance	
	n-sp	sp-gn	NL/ML	NSL/CVT	NSL/OPT	$pm\text{-}ad_1$	$pm\text{-}ad_2$	$pm\text{-}ad_3$	$tu\text{-}ad_3$	PNR(i)	PNR(e)
n-sp		0.33*	-0.09	0.38*	0.41*	-0.46**	-0.32	0.28	-0.29	-0.45*	-0.46**
sp-gn	0.33*		0.58***	0.30	0.26	-0.17	0.11	0.64***	-0.08	-0.17	-0.21
NL/ML	-0.09	0.58***		0.30	0.22	-0.04	0.07	0.39*	0.04	-0.18	-0.17
NSL/CVT	0.38*	0.30	0.30		0.95***	-0.23	-0.24	0.30	-0.26	-0.18	-0.17
NSL/OPT	0.41*	0.26	0.22	0.95***		-0.21	-0.24	0.31	-0.21	-0.33*	-0.31
$pm\text{-}ad_1$	-0.46**	-0.17	-0.04	-0.23	-0.21		0.90***	0.33*	0.39*	0.12	0.06
$pm\text{-}ad_2$	-0.32	0.11	0.07	-0.24	-0.24	0.90***		0.54**	0.40*	0.02	-0.03
$pm\text{-}ad_3$	0.28	0.64***	0.39*	0.30	0.31	0.33*	0.54**		0.15	-0.29	-0.35*
$tu\text{-}ad_3$	-0.29	-0.08	0.04	-0.26	-0.21	0.39*	0.40*	0.15		-0.03	-0.12
PNR(i)	-0.45*	-0.17	-0.18	-0.18	-0.33	0.12	0.02	0.29	-0.03		0.96***
PNR(e)	-0.46**	-0.21	-0.17	-0.17	-0.31	0.06	-0.03	-0.35*	-0.12	0.96***	

* $p \leq 0.05$

** $p \leq 0.01$

*** $p \leq 0.001$

i) **Head posture and face height**

The correlations between face height variables and head posture variables are given in Table 35 for the control group, Table 36 for cleft lip (CL), Table 37 for cleft palate (CP) and Table 38 for unilateral cleft lip and palate (UCLP).

Within the control group a larger cranio-cervical angulation (NSL/CVT, NSL/OPT) was seen with larger face height dimensions (n-sp, sp-gn, NL/ML) (Table 35), in the order of r=0.24 to r=0.43. Positive associations existed between the two cranio-cervical variables (NSL/CVT, NSL/OPT) and lower face height (sp-gn) (r=0.43, r=0.37 respectively; p<0.01), and between upper face height (n-sp) (r=0.37 p<0.05, r=0.35 p<0.05 respectively). Moderate positive values of correlation coefficients between the angular measurement of lower face height (NL/ML) and cranio-cervical variables (NSL/CVT, NSL/OPT) fell just short of the conventional 5% level of significance (r=0.24, r=0.27). These results confirm similar findings in a previous study (Solow & Tallgren 1976).

For the cleft lip (CL) group a similar pattern of association was detected. A large lower face height (sp-gn, NL/ML) was on average seen with a large cranio-cervical angulation (NSL/CVT, NSL/OPT) (Table 36). Associations existed between head posture and lower face height measured at sp-gn (r=0.43 for NSL/CVT and r=0.28 for NSL/OPT); and for face height measured at NL/ML (r=0.56 p<0.05

for NSL/CVT and r=0.58 $p<0.05$ for NSL/OPT). However the association between upper face height (n-sp) and the cranio-cervical angles measured showed only moderate association with NSL/CVT (r=0.20) but no association with NSL/OPT (r=0.06).

In the cleft palate (CP) sample (Table 37), similar associations previously found in the control group and the cleft lip (CL) sample, between head posture and face height were seen. Positive correlation coefficients between upper face height (n-sp) ($p<0.05$), lower face height (sp-gn) ($p<0.05$), and maxillary plane to mandibular plane (ML) angulation (NL/ML) ($p<0.05$), and for cranio-cervical angulation were found. The strongest associations again existed between cranio-cervical angulations NSL/CVT, NSL/OPT and lower face height (sp-gn) (r=0.51 $p<0.05$, r=0.41 $p<0.05$ respectively).

In the unilateral cleft lip and palate group all correlation coefficients between head posture and face height were positive, with on average a large cranio-cervical angulation (NSL/CVT, NSL/OPT)seen with a large upper face height (n-sp) (r=0.38 $p<0.05$, r=0.41 $p<0.01$), large lower face height (sp-gn) (r=0.30, r=0.26), and greater maxillary to mandibular plane inclination (NL/ML) (r=0.30, r=0.22).

ii) **Airway dimension and head posture**

For the control group (Table 35), negative correlations were found between cranio-cervical angulation (NSL/CVT, NSL/OPT) and airway dimensions, the negative correlations were demonstrated between the dimensions pm-ad_1 and NSL/CVT (r=-0.13, pm-ad_2 and NSL/OPT (r=-0.15) and pm-ad_2 and NSL/CVT (r=-0.09), pm-ad_2 and NSL/OPT (r=-0.14) and between the airway dimensions tu-ad_3 and NSL/CVT (r=-0.33 $p<0.05$) and between tu-ad_3 and NSL/OPT (r=-0.39 $p<0.01$).

In the cleft lip category (CL) (Table 36) negative correlations were again found between cranio-cervical angulation and airway dimension with correlation coefficients which ranged from r=-0.05 to r=-0.34.

For the cleft palate category (CP) small positive associations were present, with increases in cranio-cervical angulation (NSL/CVT, NSL/OPT) seen with increases in airway dimensions pm-ad_1, pm-ad_2, pm-ad_3 (r=0.01 to r=0.31).

The pattern of associations seen for the unilateral cleft lip and palate category (UCLP) were similar to the findings for the controls and for the cleft lip category (CL). A greater cranio-cervical angulation was found on average with a smaller airway dimension measured by pm-ad_1, pm-ad_2, tu-ad_3.

iii) **Nasal resistance and airway dimension**

Within the control group a smaller airway dimension was found on average with a greater nasal respiratory resistance (NRR) for both expiration and inspiration for all recorded dimensions of airway adequacy (Table 35). The correlation coefficients were in the order of $r=-0.14$ to $r=-0.35$, the strongest associations being between pm-ad_1 and inspiratory resistance ($r=-0.27$) and pm-ad_1 and expiratory resistance ($r=-0.30$ $p<0.05$), tu-ad_3 and inspiratory resistance ($r=-0.35$, $p<0.05$) and tu-ad_3 and expiratory resistance ($r=-0.36$, $p<0.05$).

In the cleft lip category (CL) a negative correlation was found between airway dimension and nasal respiratory resistance (NRR) for both inspiration and expiration. The correlations were in the range $r=-0.21$ to $r=-0.37$, the distribution and magnitude of the results being similar to the control group.

Stronger negative correlations, indicating a substantial relationship, existed between nasal respiratory resistance (NRR) and the dimensions for airway adequacy (pm-ad_1, pm-ad_2, pm-ad_3) in the cleft palate category (CP); the range of values for the correlation coefficients being $r=-0.40$ ($p<0.05$), to $r=-0.61$ ($p<0.01$).

Within the unilateral cleft lip and palate category (UCLP), on average, a greater nasal respiratory resistance was found with a smaller airway dimension for pm-ad_3 and PNR(i) (r=0.29) and for pm-ad_3 and PNR(e) (r=0.35).

iv) **Airway dimension and face height**

The associations between airway dimension and face height are shown in Table 35 for the controls, Table 36 for the cleft lip (CL), Table 37 for cleft palate (CP) and Table 38 unilateral cleft lip and palate (UCLP).

Airway dimension was measured by the linear dimensions pm-ad_1, pm-ad_2, pm-ad_3, tu-ad_3 (Fig. 13) and by the rhinomanometric measurements of nasal respiratory resistance (NRR) for inspiration PNR(i) and PNR(e). Within the control group little or no relationship was seen between the dimension pm-ad_1 and pm-ad_2 and upper and lower face height but moderate positive correlations were seen between the airway dimension pm-ad_3 and both upper face height ($r=0.41$ $p<0.01$) and lower face height ($r=0.52$ $p<0.001$).

For the cleft lip category (CL) (Table 36), as with the controls, no clear associations were detected between measurements of airway adequacy and face height, but again moderate positive correlations were seen between the airway dimension pm-ad_3 and both upper face height (r=0.29) and lower face height (r=0.43).

Within the cleft palate catgegory (CP) (Table 37), a substantial positive correlation existed between the measurements for airway dimension (pm-ad_1, pm-ad_2, pm-ad_3) and upper (n-sp) and lower (sp-gn) face height ranging from $r=0.33$ to $r=0.57$.

For subjects with unilateral cleft lip and palate (UCLP (Table 38), on average a smaller airway dimension pm-ad_1 was found with an greater face height (n-sp, $r=-0.46$ $p<0.01$; sp-gn, $r=-0.17$) but a marked positive correlation was seen between pm-ad_3 and sp-gn ($r=0.64$ $p<0.001$).

For completeness, correlations were examined between airway adequacy, measured by nasal respiratory resistance (NRR), and lower face height (sp-gn). Negative correlations were found for the controls and all the cleft categories with on average a greater nasal respiratory resistance being found with a smaller lower face height.

CHAPTER 7

DISCUSSION

The present study was concerned with the development of measurement apparatus to enable reproducible recordings to be made for nasal respiratory resistance (NRR) and craniofacial morphology in a control group and a cleft lip and palate sample. This presented a number of methodological problems.

The errors in all measurement systems were tested. A reproducible natural head posture position exists that can be recorded with a very small error and the findings for the duplicate determination in the present study compare favourably with those of Siersbaek-Nielson & Solow (1982) (Table 9).

The total error for the cephalometric measurement equipment (digitiser) consisted of both equipment and operator error. The error due to reproducibility of an X co-ordinate was 0.044 cm (Table 10), for the Y co-ordinate 0.014 cm (Table 11) and for the linearity distortion over the active field of the digitiser 0.056 cm (Table 12). The total error for point placement on the radiograph included both operator error and the point location error by the digitiser which for the 57 cephalometric points used in the study ranged between 4.5% and 7.1% with no significant differences at the 5% level found between two sets of recordings of the same subsample

(Table 22).

To assess the method error for rhinomanometric recordings, duplicate determinations for both inspiration and expiration were carried out for bilateral and unilateral measurements of nasal respiratory resistance (NRR) (Tables 13-18). An analysis of the data for the first and second recordings (Table 19) showed that measurements could be made with no systematic differences and with small method errors ranging from 13.6 Pascals/cc/sec x 10^3 which represented 1.4% to 5.2% of the total variances in the control sample.

The recording of the 64 linear and angular variables that make up a standard cephalometric analysis define both bony and soft tissue points. An acetate trace consisting of 57 sequentially numbered points was constructed for each subject. This procedure was adopted to avoid the operator error being made due to an incorrect point sequence being followed.

The computer programmes written for the project prompt for each point in turn with a bleep, and the assembled data was not filed until 57 co-ordinates had been compiled for each radiograph. To further check that the correct point sequence had been followed, a pen plot of the recorded data for each subject was obtained (Fig. 12). It was then possible to superimpose the original trace on the computer compiled plot to further error check the data recording sequence. Scrutiny of the results of the statistical analysis served as a final error check to "debug" the data by detection of gross distribution errors revealed by skewness and kurtosis analysis (Tables 20-22).

The present study was commenced prior to established standards for rhinomanometry although Kern (1977, 1981) commented on the need for conformity amongst researchers for terminology, recording method and calculation of results. In 1970 the American Academy of Ophthalmology and Otolaryngology had considered these areas and published a "Report of a Committee on Standardisation of Definitions, Terms, and Symbols in Rhinomanometry". This text was, however, more of a glossary of terms, symbols and gas laws than a clear cut international recommendation.

This study has followd the latest recommendations of the Committee Report on Standardisation of Rhinomanometry (Clement 1984) although accuracy of measurement was increased by the use of a scuba type diving mask (Hansen <u>et al</u> 1984), dynamic calibration with a unit developed for the study, and visual feedback for the patient by the use of computerised recording which produced results of nasal respiratory resistance (NRR) derived from the mean of four respiratory cycles.

The recommendations included the adoption of SI units and all recordings for nasal respiratory resistance (NRR) are shown in Pascals/cc/sec which in the present study were raised to the power 3 for clarity of expression.

For practical clinical purposes, the Committee Report on Standardisation in rhinomanometry (Clement 1984) recommended the use of the resistance value calculated at a point on the curve corresponding to a pressure difference of 150 Pascals (Fig. 31). This recommendation was followed throughout the study, although the method of calculation of nasal respiratory resistance is less accurate when flow through the nasal compartments becomes turbulent. The data are therefore not representative of vigorous flow and pressure but the large differences seen between right and left side of the nasal compartments during quiet respiration, as shown in the results for subjects with cleft lip (CL) (Table 24) and unilateral cleft lip and palate (UCLP) (Table 25), are certainly valid indicators of the underlying anatomical deformity.

Other methods of evaluating the curve have been described (Broms 1979; Broms et al 1982b) and the mathematical model expressing resistance at radius 200 in a polar co-ordinate system on the curve was considered by the Committee on Standardisation equally as good as a pressure of 150 Pascals in the recommended co-ordinate system. With newer technology it may become possible to record both the laminar and turbulent flow components to calculate more accurately the values for nasal respiratory resistance.

The flow pattern of inspiratory and expiratory air is however different. On inspiration, air enters the nose and traverses the nasal valve, which is the main resistor in the nasal airway (Haight & Cole 1983; Warren et al 1984), creating turbulence. The flow is directed through the middle meatus to the choanae but a few eddies are formed in the olfactory cleft and a small amount of air passes along the floor of the nose (Cole & Haight 1984). At the site of the nasal valve, in addition to the variable alar component, resistance is regulated by septal and turbinate erectile tissue (Hasegawa et al 1979). The erectile tissue around the middle and inferior turbinates further in the nasal compartments has little or no effect on resistance to airflow in the normal nose (Haight & Cole 1983). On expiration, however, a diffuse tide of warm moist air sweeps through all parts of the nasal cavity.

The patency of the nasal airway is affected unequally by the nasal cycle and also by many different stimuli such as thermal, tactile, medication, posture, exercise, allergens, irritants and emotion. Invasive instrumentation causes a marked departure from normal function (Cole & Haight 1984; Rao & Potdar 1981; Weber et al 1981; Strohl et al 1982). During measurements of unilateral nasal respiratory resistance, a small diameter pressure recording tube was attached by adhesive tape to the nasal aperture (Figs. 29 & 30) thus avoiding any distortion likely to be caused by insertion of the recording tube into the anterior nares.

In the cleft lip category (CL), significant differences were seen between the cleft and non-cleft sides and between the cleft side and the controls with higher values recorded for the cleft side. Similar findings for the unilateral cleft lip and palate (UCLP) category seem to indicate that when the cleft deformity involves the lip and nasal aperture, which may be reduced in diameter or distorted as a result of the surgery, considerable increase in resistance on the side of the deformity is produced. In the cleft palate (CP) category, the maximum extent of this deformity is no further anteriorly than the incisive papilla and does not involve the nasal aperture. Here the findings indicate that the resistance of the right and left nasal halves do not differ significantly. The values for both inspiration and expiration were moderately increased, but only those on the left side were significantly different from the controls.

These findings would seem to indicate that when surgical repair takes place for clefts which involve lip, or lip and palate, the effect on the nasal valve produces the marked increase in unilateral nasal respiratory resistance. Results for total or bilateral nasal respiratory resistance indicate that total resistance is not significantly different for cleft lip (CL), and unilateral cleft lip and palate (UCLP), which would seem to indicate that compensation within the turbinate erectile tissue has taken place in the non-involved nostril to maintain airway patency. This is likely to have taken place at the nasal aperture in the unaffected nostril but perhaps also by the mucosa overlying the turbinates further in the bony cavum.

It is interesting to see that although subjects with cleft lip (CL) and unilateral cleft lip and palate (UCLP) have a similar pattern of effect on nasal respiratory resistance, only the lip deformity is common to both. Nasal septal deviation is, however, a frequent finding in unilateral cleft lip and palate (UCLP) (Drettner 1960), but in cleft lip (CL) alterations in craniofacial morphology are less likely (Dahl 1970). Nasal septal deviation may therefore only contribute to moderate increases in nasal respiratory resistance as seen in the rhinomanometric values for cleft palate (CP) (Table 26).

This confirms the findings of previous studies (Haight & Cole 1983; Broms 1982c) which indicate that the nasal aperture exerts the major controlling influence over resistance to airflow together with compliance of the vestibular alae against inspiratory collapse which is resisted by the resilience of the alar tissues and alar muscle activity.

Furthermore, the overall effects on craniofacial morphology of the different categories of clefting deformity which are presented in Chapter 6, confirm that a child born with a cleft lip (CL) which is subsequently repaired, exerts little overall effect on craniofacial growth. This is in direct contrast to the child with a repaired cleft lip and palate (UCLP) which affects cranial base, dental base, alveolar and soft tissue relationships.

The value for total or bilateral nasal respiratory resistance (NRR) is made up of three components, one for each nasal compartment (right and left) plus a pharyngeal component. The measurements for this pharyngeal dimension which are an indication of airway adequacy ($pm\text{-}ad_1$, $pm\text{-}ad_2$, $pm\text{-}ad_3$) for both cleft lip (CL) and unilateral cleft lip and palate (UCLP), show no significant differences than the control group. In contrast, the cleft palate subjects (CP) have smaller airway dimensions measured at $pm\text{-}ad_1$, $pm\text{-}ad_2$ and $pm\text{-}ad_3$ (Table 32).

It seems, therefore, that nasal respiratory resistance is markedly increased by surgery for lip repair which involves the structures surrounding the nasal aperture, and that septal deviation may not account for the major part of the increase. Indeed, when the results for subjects with cleft palate (CP) are scrutinised, the moderate increase in nasal respiratory resistance may be accounted for by the reduction in airway dimension of the pharynx and by possible deviation of the septum. The unilateral values recorded for cleft palate (CP) subjects show higher values for the left side, possibly indicating that most septal deviations, if present in the cleft palate category (CP), were towards the left.

The cephalometric evaluation of maxillary position in the cleft palate category (CP) showed a marked maxillary retrognathism, with shorter dental base and upwards inclination of the palatal plane leading to the smaller pharyngeal airway dimension.

The interpretative nature of the study included further consideration of the inter-reaction between airway adequacy, nasal resistance, head posture and face height. Inter-reaction between form and function in the craniofacial region has been studied previously. In normal subjects, head posture is related to facial development (Solow _et al_ 1976) and also to nasal respiratory resistance (Solow _et al_ 1979). An increase in nasal resistance has an influence on the development of the dentition and craniofacial morphology (Linder-Aronson 1970) and different categories of clefting deformity have different effects on the dentition and craniofacial form (Dahl 1970).

To explain the relationship between head posture, cranio-cervical angulation and craniofacial morphology, a hypothesis was suggested by Solow & Kreiborg (1977). Extension of the head for oral respiration due to reduced airway adequacy and increased values for nasal respiratory resistance (NRR) may induce stretching of the facial soft tissues resulting in differential forces on the facial skeleton. The resultant effect on craniofacial growth with production of greater face height (adenoidal facies) is well known. Since the vital function of head posture is to maintain airway, it would not be surprising to find raised head posture in patients with difficulties in nasal respiration due to enlarged adenoids or craniofacial deformity, such as cleft lip and palate. For the purposes of the study, it was suggested that the same associations existed in a cleft sample between morphological and postural variables that existed in a control group and a detailed correlation analysis of associations between airway adequacy, nasal resistance, head posture and face height was carried out.

The analysis of the correlation between lower face height variables and head posture variables confirm the presence of a comprehensive pattern of associations for both the control group and all the cleft categories (CL), (CP), (UCLP). On average, increases in cranio-cervical angulation measured by the angles NSL/CVT and NSL/OPT were seen with increases in lower face height. This confirms the findings of Solow & Tallgren (1977) and Solow et al (1984) for the control group and presents new information for the anomaly sample.

The presence of the associations suggests the presence of a growth co-ordinating mechanism and although this is of little predictive value, especially with a small sample size, it does show that mechanisms that exist in a control group seem to be present in the various categories of the deformity.

When the correlation coefficients for the associations between airway adequacy and head posture were examined, greater cranio-cervical angulation (NSL/CVT, NSL/OPT) was seen on average with smaller airway dimensions for the control group, the cleft lip (CL), and the unilateral cleft lip and palate (UCLP) categories. In the cleft palate category (CP) a different pattern of associations existed with on average increases in cranio-cervical angulation being found with increases in airway dimension.

In cleft palate (CP) however, the anomaly creates a considerable specific maxillary deformity. The maxilla is shorter, more retrognathic, both with regard to the cranial base and the mandible, and is inclined upwards and backwards. The smaller pharyngeal airway dimension is significant when compared to the control.

When associations between nasal respiratory resistance (NRR) and airway adequacy were examined for the control group and the cleft sample, it was found that on average, an increased nasal respiratory resistance (NRR) was found with a smaller airway dimension, but that the strongest associations existed within the cleft palate category (CP) between measurements of airway dimension (pm-ad_1, pm-ad_2, pm-ad_3) and total nasal respiratory resistance (NRR).

The associations seen between airway adequacy and face height were less well defined with no clear associations detected.

In any study involving craniofacial anomalies the sample will inevitably be small. The present investigation of subjects with clefts of the lip and palate was subdivided into the recognised categories of the deformity, each with a different embryological origin and each with a different aetiology.

In the Edinburgh area of Scotland, the distribution at birth of neonates who survive with clefts, is approximately 12 per year. The present investigation assembled a sample of 61 patients representing the total expected number of clefts in a five year period. The investigations were, however, carried out when the subjects attended for routine review and this basis of selection assured that no investigative procedure was carried out specifically for the project, but as part of the overall management of the repaired cleft deformity. This method of selection produced a wide age distribution for the cleft sample and control group with consequent effects on craniofacial growth and linear dimensions.

The relationships that have been previously reported between head posture and face height, airway adequacy and face height, and nasal respiratory resistance and face height were confirmed by the present study for both the control group and the anomaly sample. The results for the associations between airway adequacy and face height were not clearly defined for the control group or the cleft sample, but this may have been due to the size of the sample and the method of selection of the subjects.

The aim of the present investigation was both methodological, investigative and interpretative. Computer programmes were written to enable further craniofacial research to be carried out and radiographic and rhinomanometric measurement systems were developed and error tested to ensure accuracy of results presented.

The cephalometric data is available for reference and defines the effect of the various categories of cleft deformity on craniofacial growth as well as presenting normative data for further research comparisons. This data for the control group was assembled from subjects attending for routine orthodontic care and may be considered representative of the craniofacial form of children from the Edinburgh area of Scotland. The data for the anomaly sample compares well with a previous study by Dahl (1970) and confirms the morphological distinction between the cleft types. Accurate data for nasal respiratory resistance (NRR) for the various cleft types has not been presented previously and represents new understanding of upper airway resistance.

The theoretical model for the developmental relationships between craniofacial morphology (face height) and cranio-cervical angulation and airway adequacy was confirmed but interpreted with care for the associations between airway adequacy and head posture and between head posture and face height. In principle this confirms previous findings that a reduction in airway adequacy leads to neuromuscular feedback with an increase in cranio-cervical angulation, a passive stretching of the soft tissue layer covering the face with a resultant effect on face height.

The methodological aspect of the study has involved the establishment of computerised cephalometric measurement apparatus in the Department of Preventive Dentistry of the University of Edinburgh. This will enable further morphological studies to be carried out.

The development of the rhinomanometer which was a significant part of the study has established the Dental School of the University of Edinburgh as the main centre in Scotland for rhinomanometric research. Evolution of the technique of rhinomanometry is still taking place, particularly with respect to the determination of laminar and turbulent flow components. Future studies in normal and anomaly groups will benefit from the developments presented here. It is proposed to carry out further investigative studies on subjects with clefting deformity which will involve rhinomanometry and direct intranasal endoscopy to observe septal deformities associated with increased nasal respiratory resistance, utilising new mathematical formulae, to calculate turbulent and laminer flow components for both an anomaly sample and a control group.

SUMMARY OF FINDINGS

The purpose of the present investigation was to develop computerised cephalometric and rhinomanometric measurement apparatus to study craniofacial morphology, head posture and nasal airflow in subjects with clefts of the lip and palate and a control group. The material for the study was collected during the period 1982-1986.

The sample consisted of 61 patients with clefting deformity attending for orthodontic review subdivided into cleft lip (CL), cleft palate (CP) and unilateral cleft lip and palate (UCLP). Only subjects with complete expression of the anomaly were included and no subjects having had secondary surgical procedures such as pharyngeal flap were selected.

The controls consisted of 38 patients attending for orthodontic assessment without cross bites. Standardised lateral cephalometric radiographs were taken for each patient in the study using the natural head position. Reduction of radiation dosage was achieved by the use of high speed X-ray films and rare earth intensifying screens. The film cassette had an attached grid to improve image quality and a silver suspended plumbline to establish a true vertical reference.

Method error tests were examined by means of duplicate determinations for head posture, digitiser linearity, cephalometric and rhinomanometric variables.

Lateral cephalometric radiographs were digitised for each subject in the study. To examine the validity of the digitised cephalometric variables an analysis of the distribution of the deviations from normality was carried out for all the linear and angular measurements using assessments of skewness and kurtosis.

This enabled the data to be scrutinised for cephalometric point placement error and accuracy of location. A pen plot derived from the 57 reproducible digitised points was drawn for each subject. This was used as a further error check by overlay on the original trace for an exact match. Tabulation of results of the analysis of craniofacial form for the controls and cleft subjects enabled statistical comparisons to be made between the samples to detect significant differences between each category of the cleft deformity and the controls.

All subjects in the study had rhinomanometric measurements carried out to record unilateral and bilateral nasal respiratory resistance (NRR) each being administered a nasal spray of xylometazoline hydrochloride.

The results of the rhinomanometric recording indicated that the bilateral nasal resistance did not differ significantly between the cleft side and the controls. Unilateral measurements however showed higher values for the cleft side than the non-cleft side both in cleft lip (CL) and unilateral cleft lip and palate (UCLP) which may indicate that turbinate or nasal valve compensation in the non-affected side had taken place.

A detailed knowledge of craniofacial form for subjects with repaired clefts of the lip and palate is important for treatment planning both for primary and secondary surgery and for orthodontic treatment. Although different surgeons had repaired the deformities studied, the analysis of the data indicated distinct effects on craniofacial morphology for each category of clefting deformity.

For cleft lip (CL) the study highlighted the local effect of the repair with little overall effect on craniofacial form.

Subjects with cleft palate (CP), however, demonstrated a less protrusive upper lip with marked maxillary retrognathia, shorter maxillary length with backwards and upwards inclination of the palatal plane with smaller airway dimensions. Clivus length and mandibular length was smaller with greater gonial angle.

For subjects with unilateral cleft lip and palate (UCLP) more widespread effects on craniofacial structures were demonstrated. Face height was greater, most of this being due to a greater lower face height. The upper incisors were retroclined with a negative overjet present. The maxilla and mandible were retrognathic with greater degree of maxillary retrognathism resulting in reduced airway dimension. Clivus length was smaller which also affected airway dimension and cranio-cervical angulation was greater.

Correlations were calculated for three measures of face height, two of head posture and six of airway dimension for the controls and each anomaly sample. The trend towards low positive correlations existed in all groups between head posture and face height. Despite the small sample this confirms previous studies on the relationship that exists between greater cranio-cervical angulation and long face.

The groups showed a low negative correlation between airway dimension and face height apart from the cleft palate (CP) category. The smaller airway dimension increased nasal respiratory resistance (NRR) which was demonstrated by the negative correlations that exist between these variables.

Although the relationship between airway dimension and face height was less clearly defined, a larger sample may confirm the negative correlations that exist for some of these variables.

The investigation has shown that for a cleft sample, bilateral nasal respiratory resistance is not significantly increased when compared to a control group. Unilateral measurements, however, show increases which are compensated for by the unaffected nasal side. Head posture measured by cranio-cervical angulation is not therefore found to be significantly greater than in the controls apart from the unilateral cleft lip and palate (UCLP) category. This may be due to the wider effect on the anomaly on cranial base and cervical vertebral structures.

The correlations, however, confirm in principle the associations that exist between sets of morphological and postural and airway variables and support the findings of previous studies which reflect some of the co-ordinating mechanisms that govern facial growth and development.

APPENDIX 1

Lothian Area Dental Ethical Committee

11 Drumsheugh Gardens
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EH3 7QQ

Our Ref: MGW/LADC/13/2
If calling ask for: Mrs Wardell
Date: 6th August 1984

Mr J A Sandham
Consultant
Edinburgh Dental Hospital
Orthodontic Department
Chambers Street
EDINBURGH EH1 1JA

Dear Mr Sandham

Research Project - Lateral Skull Radiographs of Routine Patients and Those with Cleft Lips and Palate/Measurement of Nasal Resistance Using a Rhinomanometric Machine

I refer to your letter of 23 May 1984.

At their meeting the Lothian Area Dental Ethical Committee considered and approved your above mentioned Research Project.

The Committee would wish to receive a copy of the Report of your Project once it is completed.

Yours sincerely

J.C. Southam

Professor J C Southam
(Chairman)

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4th July 1984

Mr. J.A. Sandham,
Consultant Orthodontist,
Edinburgh Dental Hospital,
Chambers Street,
Edinburgh.

Dear Mr. Sandham,

Thank you for your letter about your research project in children with cleft lip and palate.

All of us are perfectly agreeable for any of our own patients to be included in this, and we would be interested to learn of your findings in due course.

Yours sincerely,

Anne B. Sutherland

Anne B. Sutherland, F.R.C.S.E.
Chairman, Division of Plastic Surgery.

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